Inter-American Metrology System - SIM

INSTITUTO NACIONAL DE METROLOGIA, QUALIDADE E TECNOLOGIA – INMETRO

FINAL REPORT ON SUPPLEMENTARY REGIONAL COMPARISON SIM.AUV.A-S2: CALIBRATION OF PISTONPHONE

May 13th, 2020

Authors: Thiago Antônio Bacelar Milhomem (INMETRO)
Zemar Martins Defilippo Soares (INMETRO)
Gustavo Palmeira Ripper (INMETRO)

Co-authors: Juan Pablo Ayala Breña (CENAM)
Giancarlos Miguel Guevara Chuquillanqui (INACAL)
Federico Ariel Serrano (INTI)
Adrian Solano Mena (LACOMET)
Randall P. Wagner (NIST)
Peter Hanes (NRC)

ABSTRACT

This document is the Final Report of the Inter-American Metrology System supplementary comparison on pistonphone calibration SIM.AUV.A-S2 that took place between September 2018 and January 2020. Seven national metrology institutes participated on this comparison: CENAM/Mexico, INACAL/Peru, INMETRO/Brazil, INTI/Argentina, LACOMET/Costa Rica, NIST/USA and NRC/Canada. INMETRO was the pilot institute responsible for the coordination of this comparison. One pistonphone was circulated among the participants to carry out calibrations according to the international standard IEC 60942:2017 using both LS1P and LS2P measurement microphones. Beyond the mandatory measurement of the sound pressure level, it was requested to the participants report measurement results of frequency, total harmonic distortion and total distortion + noise (measured over a bandwidth of 22.4 Hz to 22.4 kHz) for the purpose of investigation. For sound pressure level and frequency measurement results, supplementary comparison reference values (SCRVs) were determined using the weighted mean method and the corresponding degrees of equivalence between each participant and the SCRV are presented. All participants presented consistent results. For total harmonic distortion and total distortion + noise measurements, SCRVs were not calculated and the values reported by participants are compared with the calculated arithmetic mean and weighted mean values. Overall, the supplementary comparison SIM.AUV.A-S2 was considered successful and fit its purpose.

CONTENT

1 INTRODUCTION

The supplementary comparison SIM.AUV.A-S2 is the second comparison on pistonphone calibration carried out under the auspices of the Inter-American Metrology System (SIM). Seven national metrology institutes (NMIs), all belonging to the SIM, participated on this comparison and one pistonphone was circulated between them. Each participant used its own technical procedure in addition to the agreed technical protocol. This report presents the history relative to the technical protocol approval, lists the participating institutes, details the traveling pistonphone, describes the statistical criteria for performance assessment, presents the results reported by the participants, evaluates statistically the institutes' performance, and provides comments on the results obtained.

2 COMPARISON PROTOCOL

On April 2018, a first proposal of technical protocol on pistonphone calibration was prepared by the pilot institute and circulated between the members of SIM Metrology Working Group (MWG-9) for comments. Shortly after this, a revised version was circulated for approval. After the approval by the MWG-9 members, on May 2018, it was submitted to the Key Comparison Working Group (KCWG) of the Consultative Committee for Acoustics, Ultrasound and Vibration (CCAUV) for review. The final technical protocol [1] was approved by the KCWG on August 2018, and it was published together with the supplementary comparison registration and progress form on the Key Comparison Data Base (KCDB) of the *Bureau International des Poids et Mesures* (BIPM). Two supplements were issued later. The first one, issued on April 2019, changed the order of participation between two NMIs and introduced a little shift on the timetable. This was done to take advantage of a technical meeting to transfer the pistonphone by hand from one participant to another one. All involved NMIs were consulted and agreed with this schedule adjustment. The second one, issued on July 2019, introduced another shift on the timetable due to the pistonphone retention in customs.

3 PARTICIPANTS AND TIMETABLE

3.1 Participants

The participating NMIs were: Centro Nacional de Metrología (CENAM, from Mexico); Instituto Nacional de Calidad (INACAL, from Peru); Instituto Nacional de Metrologia, Qualidade e Tecnologia (INMETRO, from Brazil); Instituto Nacional de Tecnología Industrial (INTI, from Argentina); Laboratorio Costarricense de Metrologia (LACOMET, from Costa Rica); National Institute of Standards and Technology (NIST, from USA); and National Research Council Canada (NRC, from Canada). The role of pilot institute was undertaken by INMETRO.

3.2 Timetable

Measurements took place between September 2018 and January 2020. The time schedule was organized considering the circulation of the pistonphone in a ring configuration, with an intermediate stability check by the pilot institute. The sequence of participants was chosen in order to optimize the transportation of the pistonphone between them. The actually performed measurement and circulation timetable of the pistonphone is presented in Table 1.

Table 1 – Measurement and circulation timetable of the pistonphone.

National Metrology Institute	**Period for measurements**
INMETRO	September 24th to October 5th, 2018
Transportation of the pistonphone by previous NMI to the next one	
NRC	October 22nd to November 2nd, 2018
Transportation of the pistonphone by previous NMI to the next one	
NIST	November 19th to 30th, 2018
Transportation of the pistonphone by previous NMI to the next one	
CENAM	December 17th, 2018 to January 11th, 2019
Transportation of the pistonphone by previous NMI to the next one	
INMETRO	January 28th to February 8th, 2019
Transportation of the pistonphone by previous NMI to the next one	
INTI	February 25th to March 15th, 2019
Transportation of the pistonphone by previous NMI to the next one	
LACOMET	April 8th to 19th, 2019
Transportation of the pistonphone by previous NMI to the next one	
INACAL	July 18th to August 26th, 2019
INACAL	October 14th to 22nd, 2019
Transportation of the pistonphone by previous NMI to the next one	
INMETRO	December 2nd, 2019 to January 2nd, 2020

INMETRO carried out measurements in three periods during the pistonphone circulation, but only the results obtained during the first period were used for comparison with the supplementary comparison reference value (SCRV). The results obtained during the second and third periods were used only to check the pistonphone's stability.

INACAL carried out measurements in two periods during the pistonphone circulation. The first one, before a request from the pilot institute to check and confirm its results (more details in item 6). The second one was after this request. Only the results obtained during the second period were used for comparison with the SCRV. It should be noted that the pilot institute was not consulted by INACAL about its desire to make new measurements and only became aware of this when analyzing the revised documentation submitted after the request for check and confirmation of its data. These new measurements were possible because INACAL had difficulties to return of the pistonphone to INMETRO and it was kept for a longer period than initially expected. As the SCRV had not been disclosed, the coordination of this comparison understood that there was no problem in using the results obtained during the second period, since this occurrence was registered.

4 TRAVELING PISTONPHONE

4.1 Pistonphone

The artefact circulated among the institutes was one pistonphone manufactured by Brüel and Kjaer, type 4228 [2] and serial number 2836183, with its one-inch to half-inch adaptor type DP 0776 (for coupling of LS2P measurement microphones) and its user manual.

Each participant had to calibrate the pistonphone using the microphone method (insert voltage technique) and report the generated sound pressure level. Reports of frequency, total harmonic distortion and total distortion + noise (measured over a bandwidth of 22.4 Hz to 22.4 kHz) of the sound pressure level generated by the pistonphone were also suggested for the purpose of investigation. Total harmonic distortion is defined as the ratio of the root-mean-square (rms) value of the harmonic content to the rms value of the fundamental component or the reference fundamental component of an alternating quantity [3]. On the other side, total distortion + noise is the ratio of the rms of the total distortion and noise components, including any harmonics and sub-harmonics, to the rms of the entire signal [4].

All measurements were to be performed using both a LS2P and a LS1P measurement microphone. In the case of a participant being able to perform measurements with only one type of microphone, then the report of results should clearly state which type of microphone was used. The pistonphone circulated between the participants is owned by INMETRO, who kindly supplied it for this project.

4.2 Stability check

INMETRO checked the pistonphone's stability before the beginning of circulation, during the comparison and after the end of circulation. This checking consisted of pistonphone calibrations by the microphone method using the insert voltage technique in order to obtain the generated sound pressure level, frequency, total harmonic distortion and total distortion + noise (measured over a bandwidth of 22.4 Hz to 22.4 kHz). All stability measurements were performed using a LS2P and a LS1P measurement microphone. Figures 1 to 8 show the differences of measured values at each check calibration with respected to their common average. No significant trend was observed, although notable variances in the measured values of total harmonic distortion and total distortion + noise, with respect to the reported measurement uncertainty, were observed.

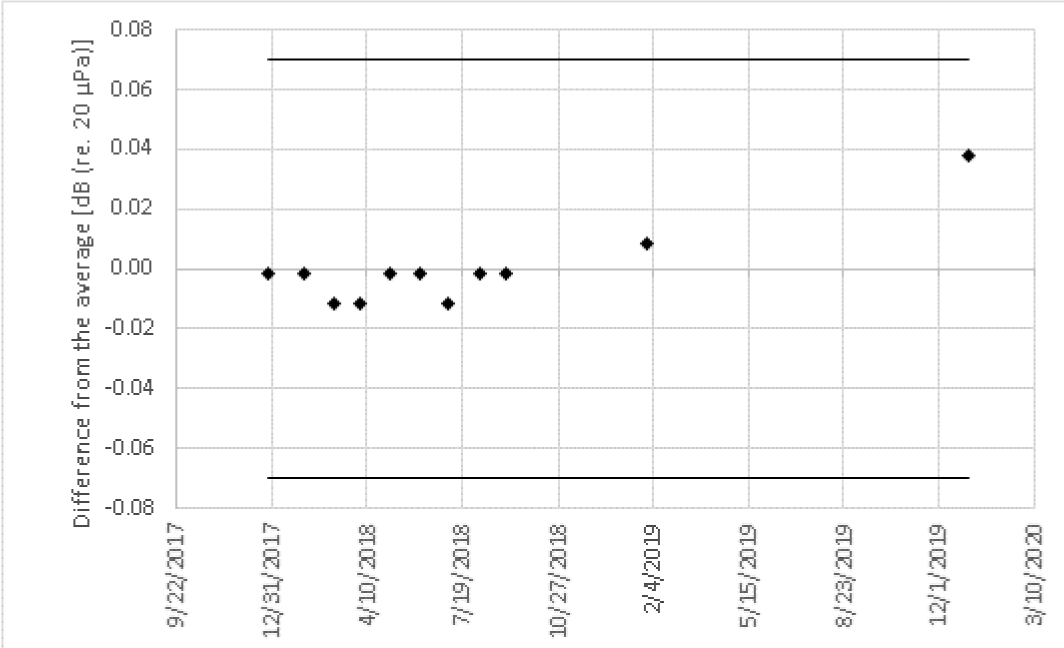


Figure 1 – Differences of the sound pressure levels measured using a LS2P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

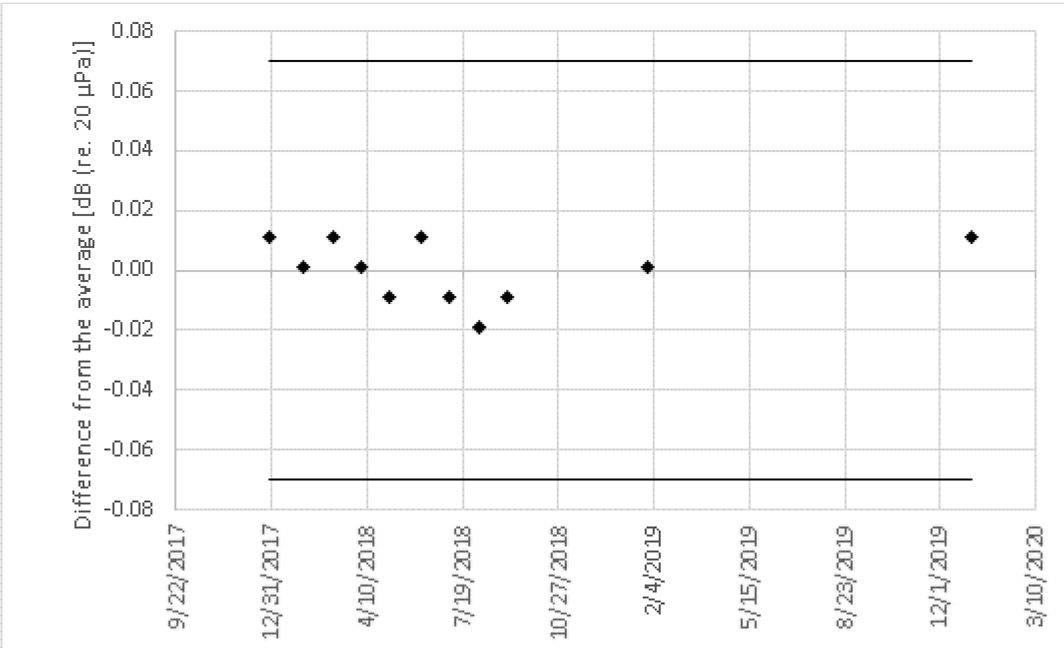


Figure 2 – Differences of the sound pressure levels measured using a LS1P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

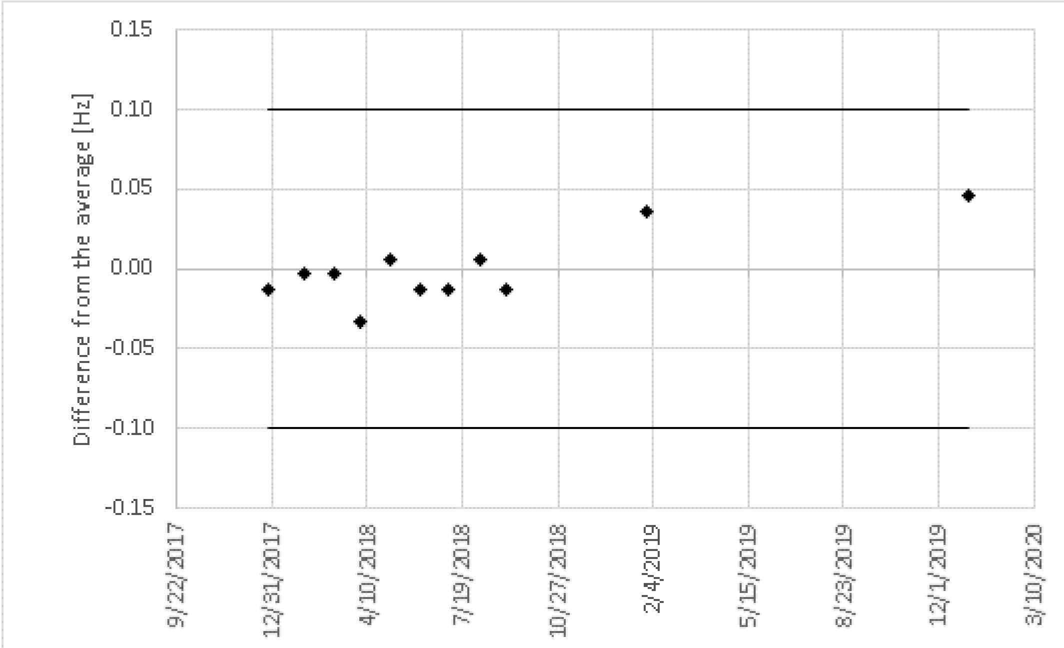


Figure 3 – Differences of the frequencies measured using a LS2P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

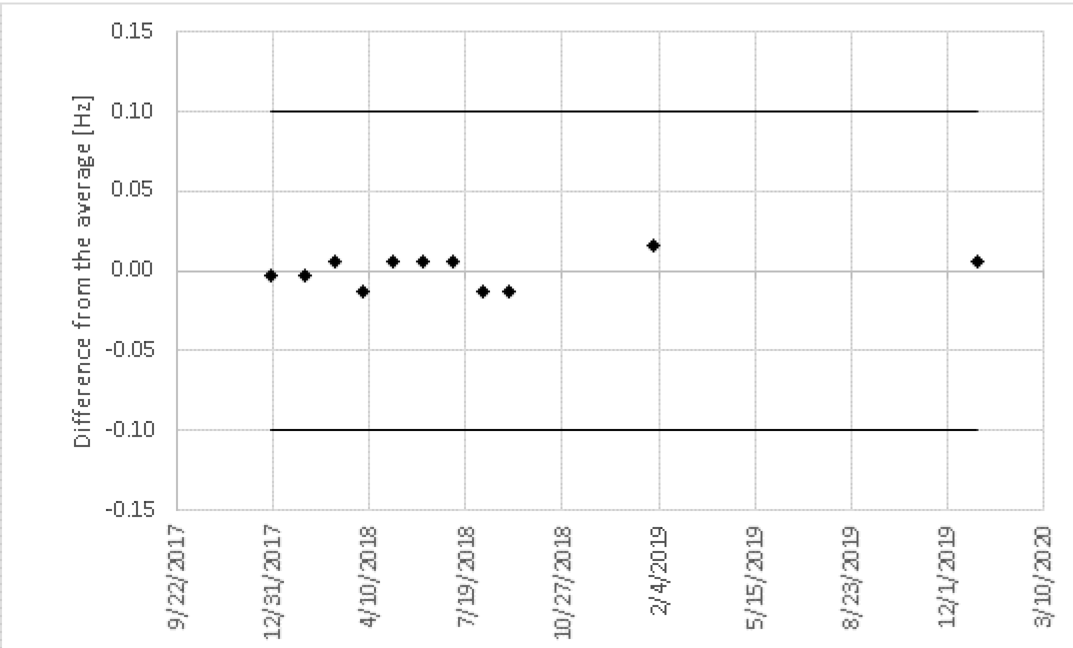


Figure 4 – Differences of the frequencies measured using a LS1P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

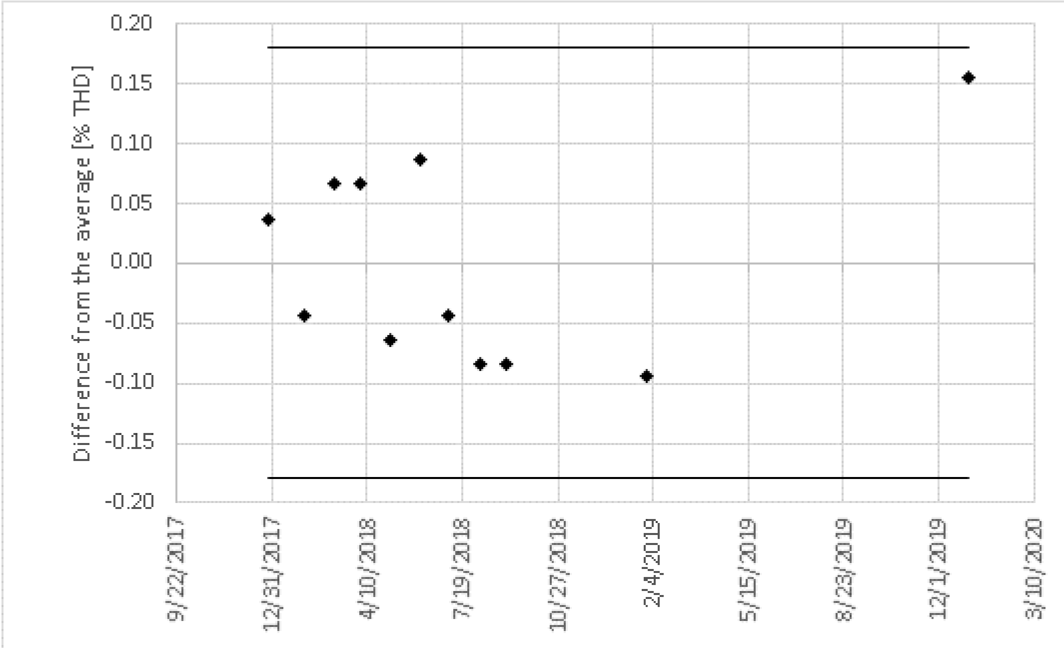


Figure 5 – Differences of total harmonic distortion measured using a LS2P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

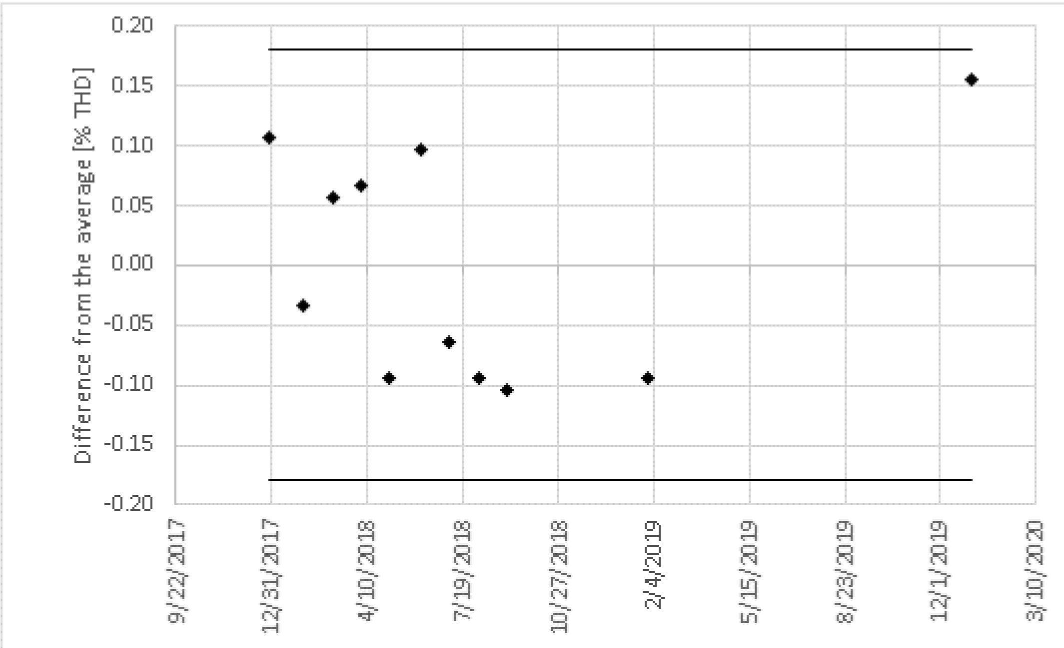


Figure 6 – Differences of total harmonic distortion measured using a LS1P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

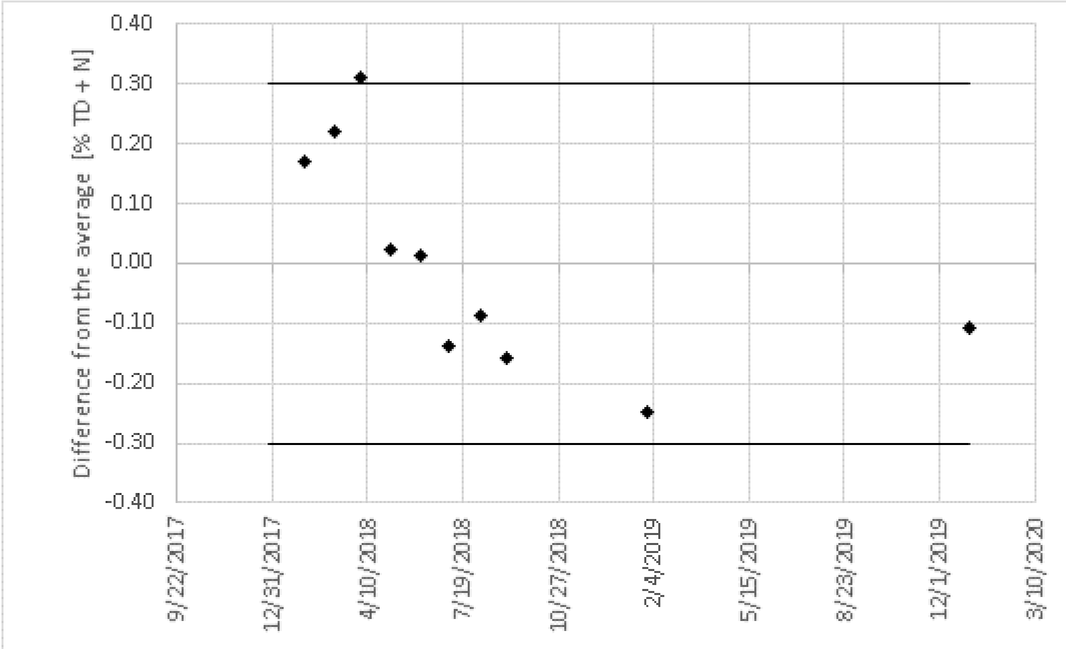


Figure 7 – Differences of total distortion + noise measured using a LS2P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

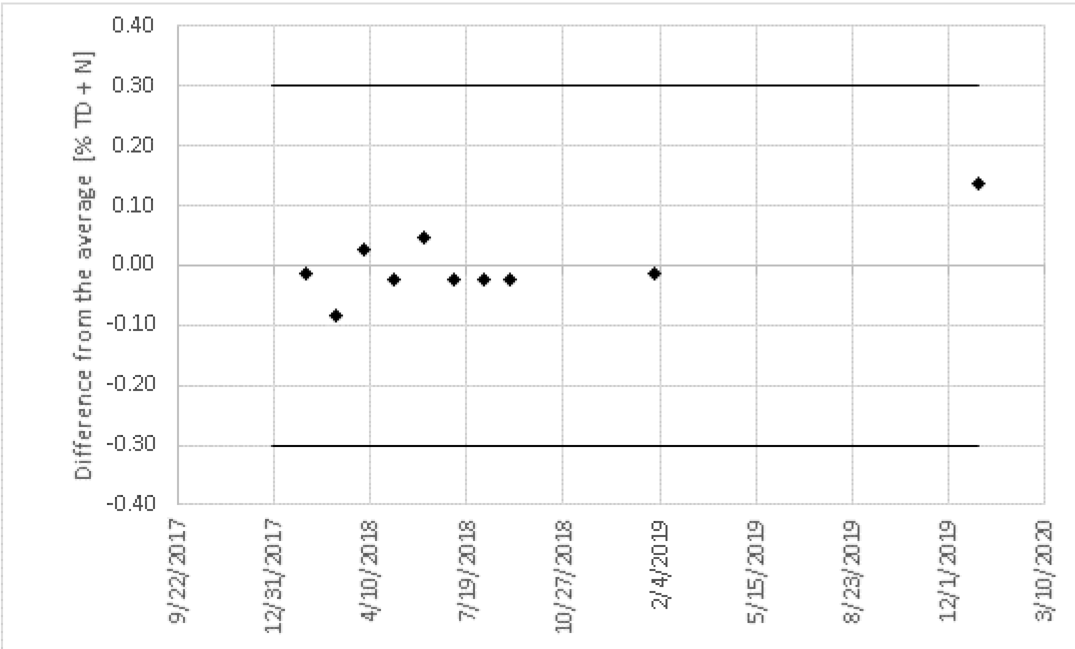


Figure 8 – Differences of total distortion + noise measured using a LS1P microphone at each check calibration with respect to their common average. Uncertainty bounds are shown.

5 STATISTICAL CRITERIA FOR PERFORMANCE ASSESSMENT

Performance assessment was made using the Procedure A presented by M. G. Cox in the paper "The Evaluation of Key Comparison Data" [5] and the Procedure Full

Enumeration also shown by M. G. Cox in the paper “The Evaluation of Key Comparison Data: Determining the Largest Consistent Subset” [6].

In summary, the weighted mean (using the standard uncertainty as weighting factor) and its standard deviation are determined. Then, the chi-squared test (with a probability of 5 %) is applied to carry out an overall consistency check of the measurement results. When the consistency does not fail, the weighted mean is accepted as the SCRV, its standard deviation is accepted as the standard uncertainty and the degrees of equivalence are calculated. When the consistency check fails, anomalous measurement results are identified (comparing the differences between the results and the weighted mean with the uncertainties of those differences) and the corresponding institutes are invited to check their results for any numerical errors. If no numerical error is found, then a new weighted mean and its standard deviation are determined after removing the most anomalous measurement result and the process is re-started. On the other side, if a numerical error is found, a new weighted mean and its standard deviation are determined considering the new value and the process is re-started.

6 REPORTED RESULTS

The participants were requested to report their results using a spreadsheet template previously sent by the pilot institute. The value of the measurand was to be presented with one extra decimal figure than its respective uncertainty. The pilot institute rounded the results of each participant to the same number of decimal figures of the reported uncertainty. In addition to the template, a formal calibration certificate usually issued by the participant and an uncertainty budget were requested.

The results reported by each participant were analyzed according to item 5. An anomalous measurement result was identified in the submitted results of INACAL for sound pressure level measured using a LS2P microphone. In accordance with the CIPM MRA guidelines [7], INACAL was invited to check its results. It was informed on the parameter of the anomalous measurements results (for example, sound pressure level), but it was not informed about the type of microphone associated to the data (for example, LS2P measurement microphone).

INACAL carried out new measurements, which were possible due to difficulties to return the pistonphone to INMETRO and it was kept for a longer period in Peru than initially expected (see subitem 3.2 for more details). Therefore, INACAL reviewed its results and submitted new values for all measured parameters, i.e. results for sound pressure level, frequency and total harmonic distortion measured using a LS2P microphone. The new set of results were analyzed again and no anomalous measurement results was identified. The first and the revised sets of results submitted by INACAL are summarized in Appendix A. The two full spreadsheets reported by INACAL are presented in Appendix B.

The final reported results are shown in Figures 9 to 16 and Tables 2 to 9. Participants are presented according to the order of their participation. The spreadsheet templates filled by each participant are presented in Appendix B and uncertainty budgets for sound pressure level measurements sent by each participant are presented in Appendix C. The report of sound pressure level measurement was mandatory, while reports of frequency, total harmonic distortion and total distortion + noise measurements were just suggested for the purpose of investigation.

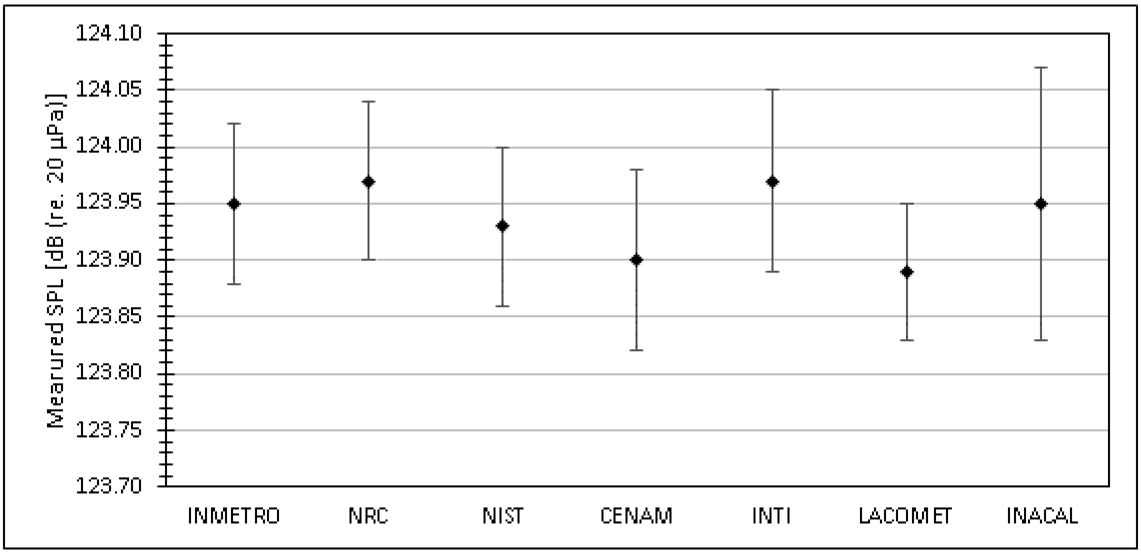


Figure 9 – Results reported by participants: Sound pressure level (corrected for load volume and for the reference environmental conditions) measured using a LS2P microphone.

Table 2 – Results reported by participants: Sound pressure level (corrected for load volume and for the reference environmental conditions) measured using a LS2P microphone.

NMI	**Measured SPL [dB (reference: 20 µPa)]**	**Expanded Uncertainty 95 %, *k* = 2 [dB (reference: 20 µPa)]**
INMETRO	123.95	0.07
NRC	123.97	0.07
NIST	123.93	0.07
CENAM	123.90[a]	0.08[a]
INTI	123.97	0.08
LACOMET	123.89	0.06
INACAL	123.95[b,c]	0.12[b,c,d]

<u>Notes:</u>

[a] The SPL was measured by the "direct measurement" method. Despite of the technical protocol [1] stating that it should be measured by the microphone method (insert voltage technique), the measurement result was considered for comparison purposes.

[b] The SPL was measured by the sound calibrator comparison method. Despite of the technical protocol [1] stating that it should be measured by the microphone method

(insert voltage technique), the measurement result was considered for comparison purposes.

[c] Revised value.

[d] Despite of the uncertainty of measurement exceeding the maximum-permitted value (± 0.10 dB) stated in IEC 60942:2017 [4], the measurement result was considered for comparison purposes.

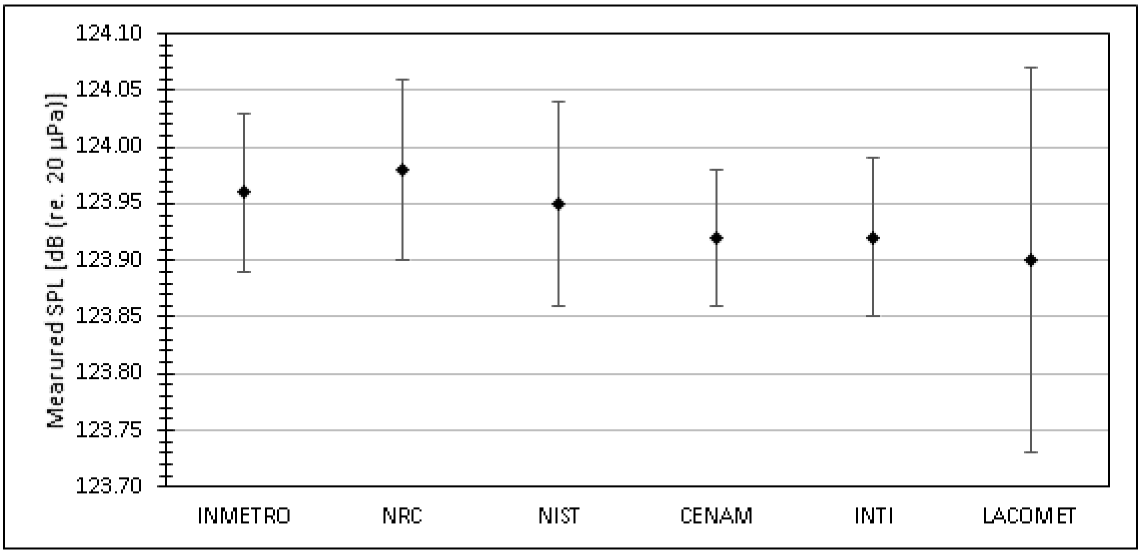


Figure 10 – Results reported by participants: Sound pressure level (corrected for load volume and for the reference environmental conditions) measured using a LS1P microphone.

Table 3 – Results reported by participants: Sound pressure level (corrected for load volume and for the reference environmental conditions) measured using a LS1P microphone.

NMI	**Measured SPL [dB (reference: 20 µPa)]**	**Expanded Uncertainty 95 %, *k* = 2 [dB (reference: 20 µPa)]**
INMETRO	123.96	0.07
NRC	123.98	0.08
NIST	123.95	0.09
CENAM	123.92[a]	0.06[a]
INTI	123.92	0.07
LACOMET	123.90	0.17[b]
INACAL	Not reported	Not reported

Notes:

[a] The SPL was measured by the “direct measurement” method. Despite of the technical protocol [1] stating that it should be measured by the microphone method (insert voltage technique), the measurement result was considered for comparison purposes.

[b] Despite of the uncertainty of measurement exceeding the maximum-permitted value (± 0.10 dB) stated in IEC 60942:2017 [4], the measurement result was considered for comparison purposes. (See Appendix D, for LACOMET comments).

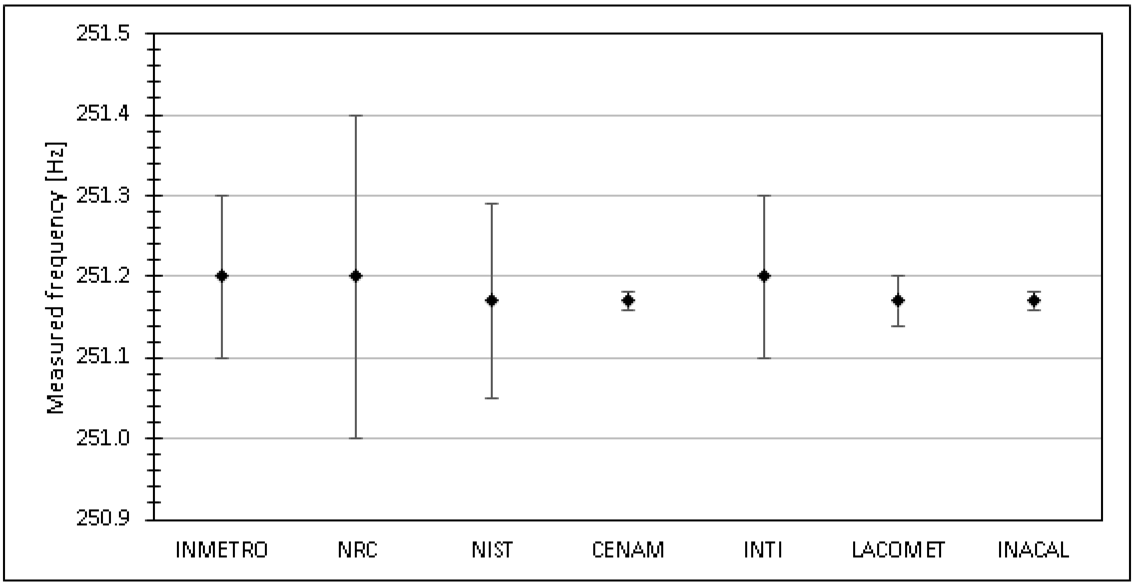


Figure 11 – Results reported by participants: Frequency measured using a LS2P microphone.

Table 4 – Results reported by participants: Frequency measured using a LS2P microphone.

NMI	Measured Frequency [Hz]	Expanded Uncertainty 95 %, *k* = 2 [Hz]
INMETRO	251.2	0.1
NRC	251.2	0.2
NIST	251.17	0.12
CENAM	251.17	0.01
INTI	251.2	0.1
LACOMET	251.17	0.03
INACAL	251.17[a]	0.01[a]

Note:
[a] Revised value.

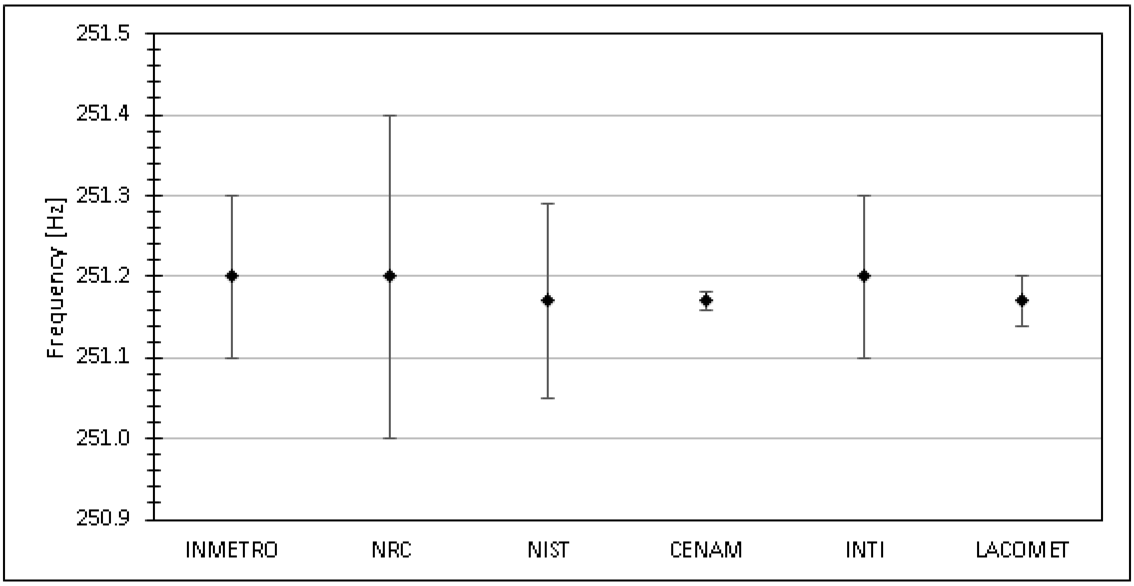


Figure 12 – Results reported by participants: Frequency measured using a LS1P microphone.

Table 5 – Results reported by participants: Frequency measured using a LS1P microphone.

NMI	**Measured Frequency [Hz]**	**Expanded Uncertainty 95 %, *k* = 2 [Hz]**
INMETRO	251.2	0.1
NRC	251.2	0.2
NIST	251.17	0.12
CENAM	251.17	0.01
INTI	251.2	0.1
LACOMET	251.17	0.03
INACAL	Not reported	Not reported

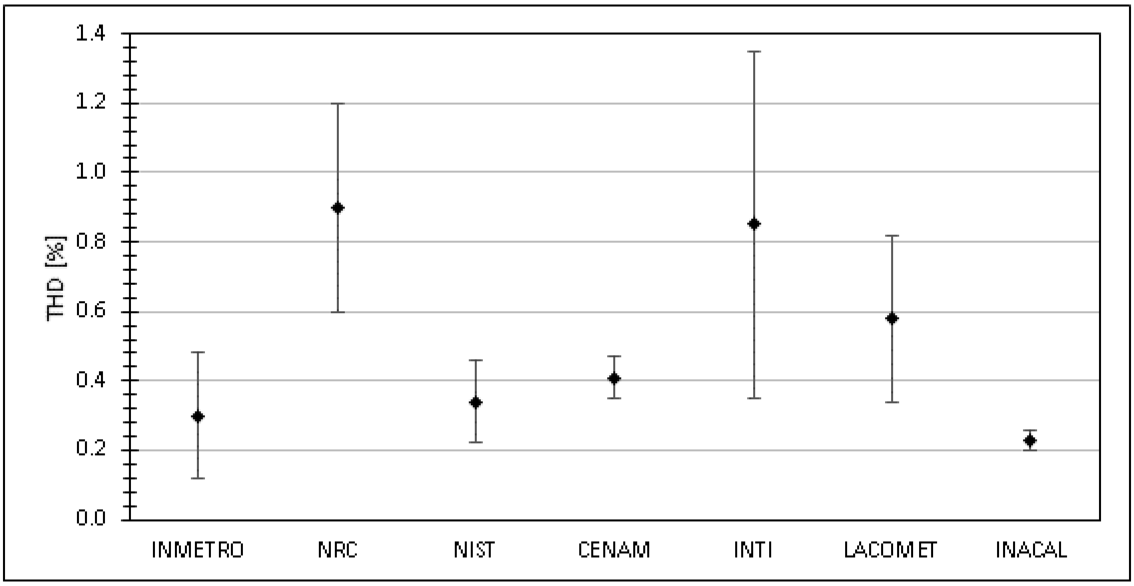


Figure 13 – Results reported by participants: Total harmonic distortion measured using a LS2P microphone.

Table 6 – Results reported by participants: Total harmonic distortion measured using a LS2P microphone.

NMI	**Measured THD [%]**	**Expanded Uncertainty 95 %, *k* = 2 [%]**
INMETRO	0.30	0.18
NRC	0.9	0.3
NIST	0.34	0.12
CENAM	0.41	0.06
INTI	0.85	0.50
LACOMET	0.58	0.24
INACAL	0.23[a]	0.03[a]

Note:

[a] Revised value.

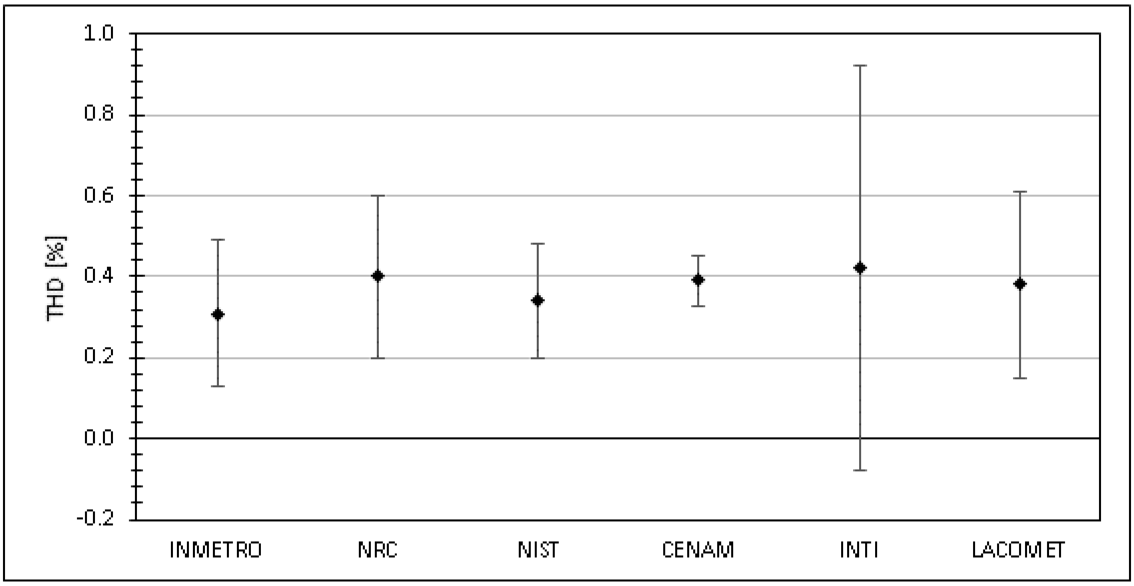


Figure 14 – Results reported by participants: Total harmonic distortion measured using a LS1P microphone.

Table 7 – Results reported by participants: Total harmonic distortion measured using a LS1P microphone.

NMI	**Measured THD [%]**	**Expanded Uncertainty 95 %, *k* = 2 [%]**
INMETRO	0.31	0.18
NRC	0.4	0.2
NIST	0.34	0.14
CENAM	0.39	0.06
INTI	0.42	0.50
LACOMET	0.38	0.23
INACAL	Not reported	Not reported

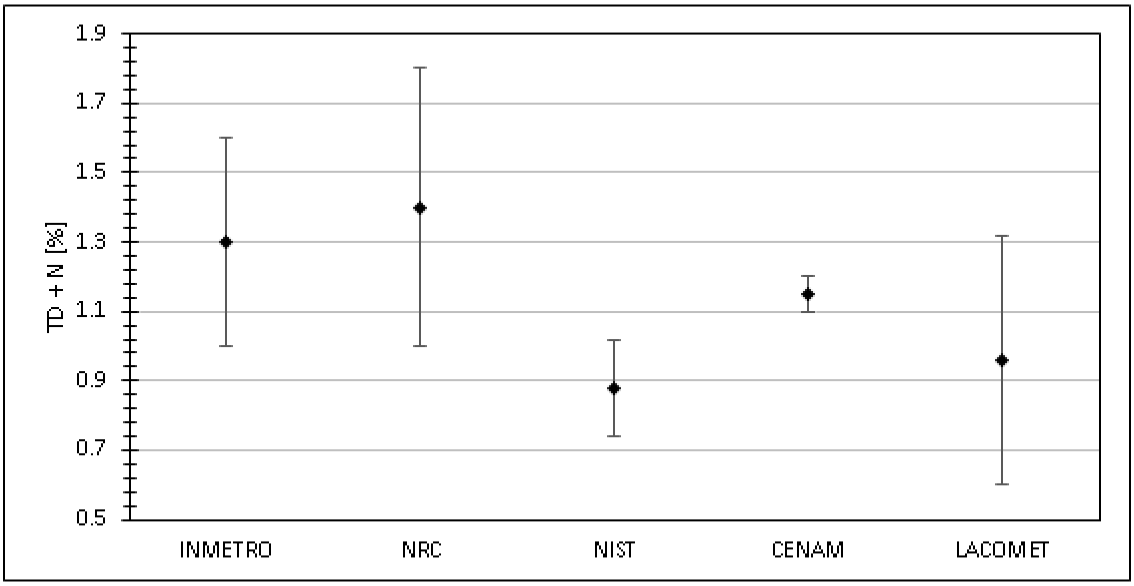


Figure 15 – Results reported by participants: Total distortion + noise measured using a LS2P microphone.

Table 8 – Results reported by participants: Total distortion + noise measured using a LS2P microphone.

NMI	**Measured TD + N [%]**	**Expanded Uncertainty 95 %, *k* = 2 [%]**
INMETRO	1.30	0.30
NRC	1.4	0.4
NIST	0.88[a]	0.14[a]
CENAM	1.15	0.05
INTI	Not reported	Not reported
LACOMET	0.96	0.36
INACAL	Not reported	Not reported

Note:

[a] Revised value.

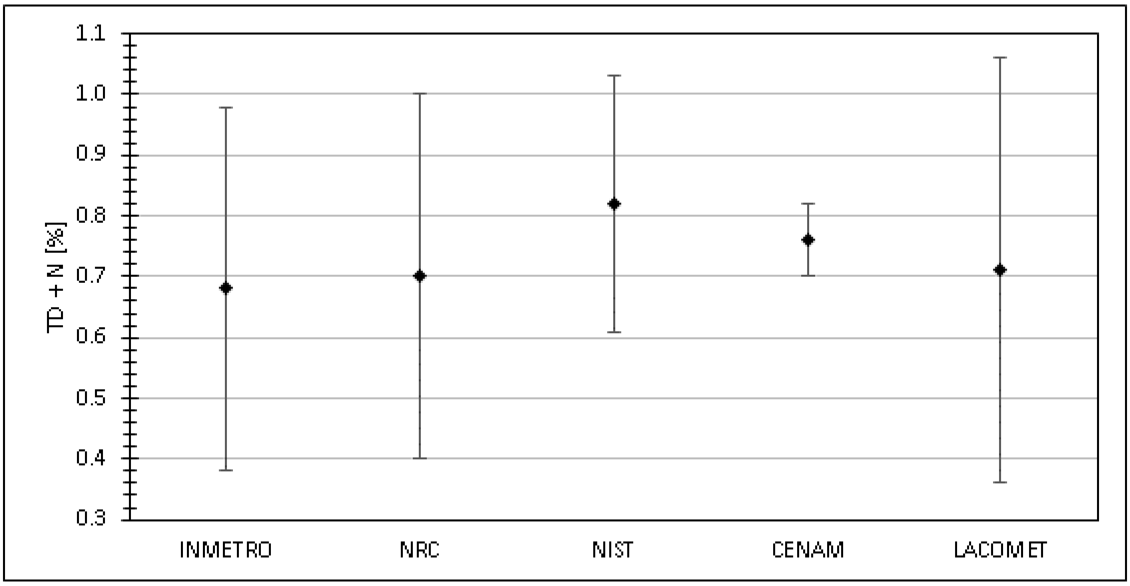


Figure 16 – Results reported by participants: Total distortion + noise measured using a LS1P microphone.

Table 9 – Results reported by participants: Total distortion + noise measured using a LS1P microphone.

NMI	Measured TD + N [%]	Expanded Uncertainty 95 %, k = 2 [%]
INMETRO	0.68	0.30
NRC	0.7	0.3
NIST	0.82[a]	0.21[a]
CENAM	0.76	0.06
INTI	Not reported	Not reported
LACOMET	0.71	0.35
INACAL	Not reported	Not reported

Note:
[a] Revised value.

7 STATISTICAL EVALUATION OF INSTITUTES' PERFORMANCE

7.1 Supplementary comparison reference values for sound pressure level and frequency

Tables 10 and 11 show the SCRVs for measurements using a LS2P and a LS1P microphone respectively. The results reported by all participants were used to calculate them. No correlations between the participants were accounted for in the following analysis.

Table 10 – SCRV for measurements using a LS2P microphone.

	Measurand	Expanded Uncertainty 95 %, k = 2
SPL [dB (reference: 20 μPa)]	123.93	0.03
Frequency [Hz]	251.17	0.01

Table 11 – SCRV for measurements using a LS1P microphone.

	Measurand	**Expanded Uncertainty 95 %, *k* = 2**
SPL [dB (reference: 20 μPa)]	123.94	0.03
Frequency [Hz]	251.17	0.01

7.2 Degrees of equivalence for sound pressure level and frequency

According to the CIPM MRA guidelines [7] it is not a requirement to report the degrees of equivalence (DoE) for a supplementary comparison. However, the DoEs have been calculated and reported with its expanded uncertainty, *U*(DoE). Figures 17 to 20 and Tables 12 to 15 show the DoEs and respective expanded uncertainty, *U*(DoE), for measurements using a LS2P and a LS1P microphone.

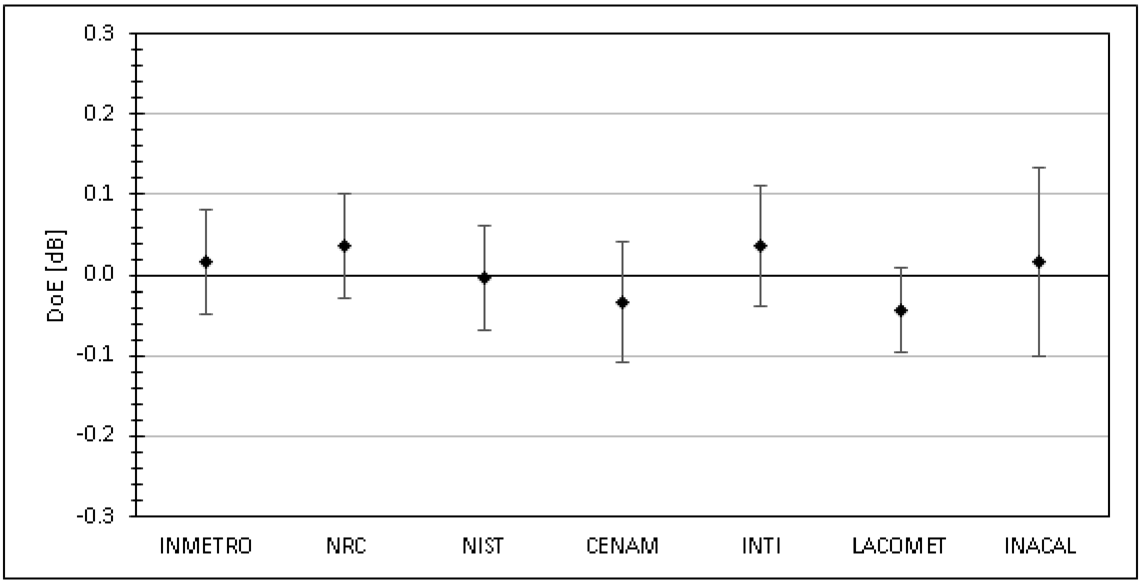


Figure 17 – Degrees of equivalence of the sound pressure level results measured using a LS2P microphone.

Table 12 – Degrees of equivalence of the sound pressure level results measured using a LS2P microphone.

NMI	**DoE of Measured SPL [dB (reference: 20 μPa)]**	**Expanded Uncertainty 95 %, *k* = 2 [dB (reference: 20 μPa)]**
INMETRO	0.02	0.06
NRC	0.04	0.06
NIST	0.00	0.06
CENAM	-0.03	0.07
INTI	0.04	0.07
LACOMET	-0.04	0.05
INACAL	0.02	0.12

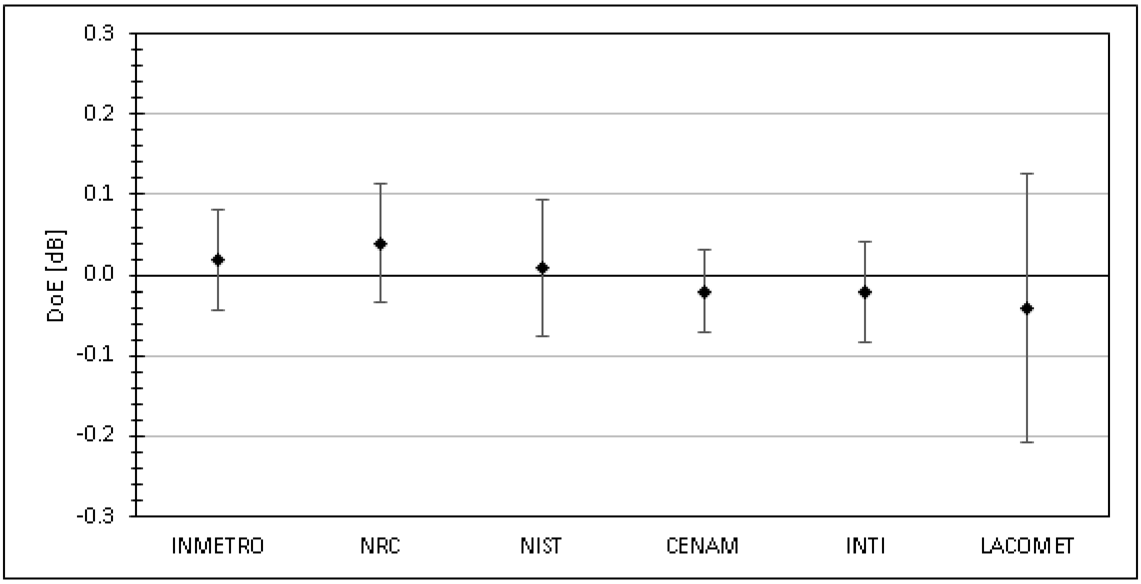


Figure 18 – Degrees of equivalence of the sound pressure level results measured using a LS1P microphone.

Table 13 – Degrees of equivalence of the sound pressure level results measured using a LS1P microphone.

NMI	**DoE of Measured SPL [dB (reference: 20 μPa)]**	**Expanded Uncertainty 95 %, *k* = 2 [dB (reference: 20 μPa)]**
INMETRO	0.02	0.06
NRC	0.04	0.07
NIST	0.01	0.08
CENAM	-0.02	0.05
INTI	-0.02	0.05
LACOMET	-0.04	0.17
INACAL	Not applicable	Not applicable

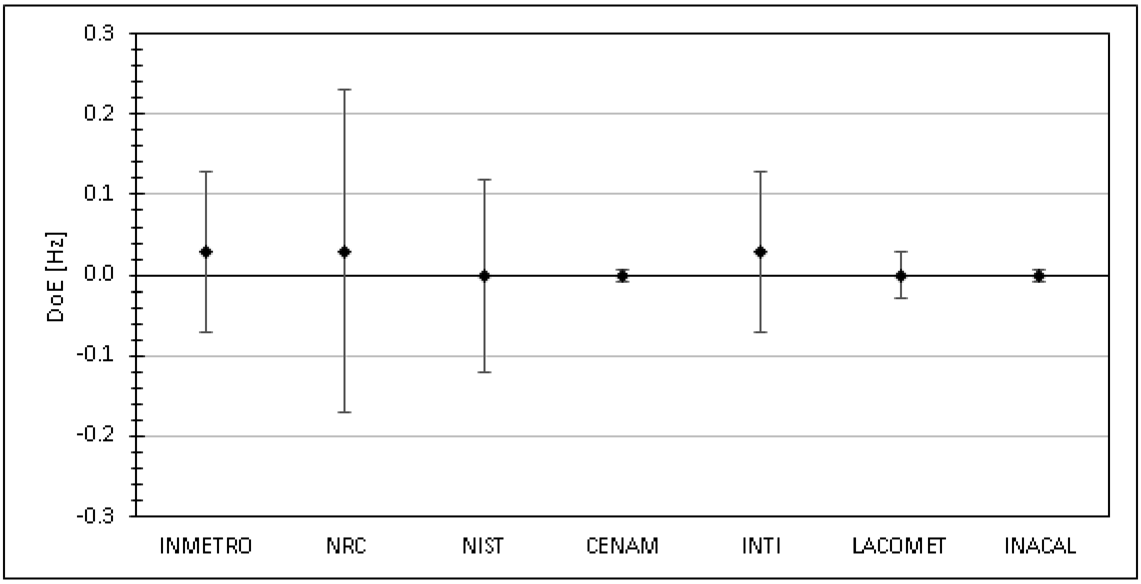


Figure 19 – Degrees of equivalence of the frequency results measured using a LS2P microphone.

Table 14 – Degrees of equivalence of the frequency results measured using a LS2P microphone.

NMI	DoE of Measured Frequency [Hz]	Expanded Uncertainty 95 %, *k* = 2 [Hz]
INMETRO	0.03	0.10
NRC	0.03	0.20
NIST	0.00	0.12
CENAM	0.00	0.01
INTI	0.03	0.10
LACOMET	0.00	0.03
INACAL	0.00	0.01

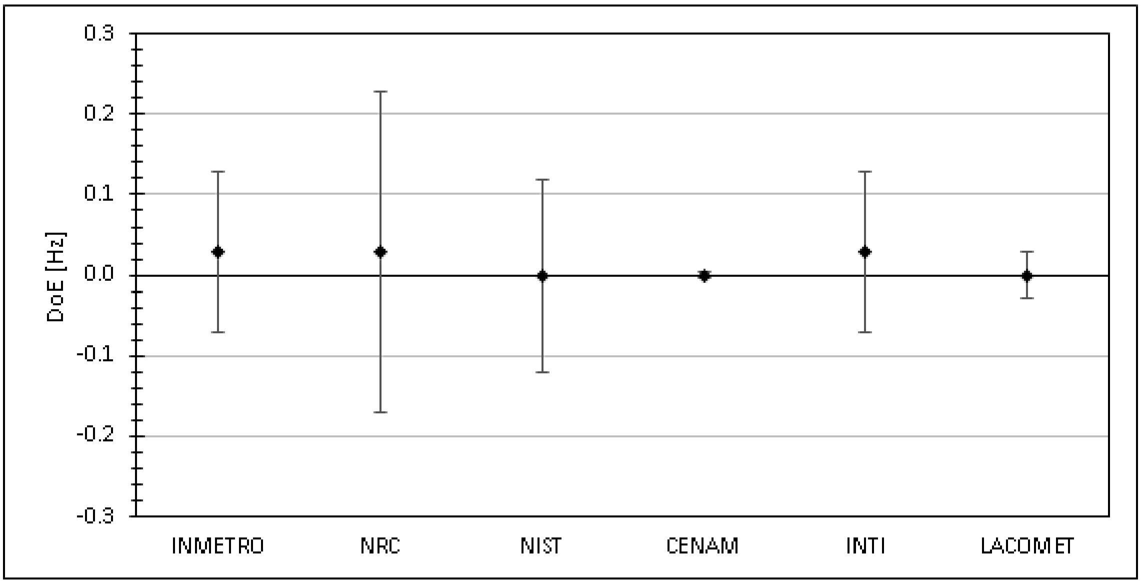


Figure 20 – Degrees of equivalence of the frequency results measured using a LS1P microphone.

Table 15 – Degrees of equivalence of the frequency results measured using a LS1P microphone.

NMI	**DoE of Measured Frequency [Hz]**	**Expanded Uncertainty 95 %, *k* = 2 [Hz]**
INMETRO	0.03	0.10
NRC	0.03	0.20
NIST	0.00	0.12
CENAM	0.00	0.01
INTI	0.03	0.10
LACOMET	0.00	0.03
INACAL	Not applicable	Not applicable

7.3 Mean values calculated for total harmonic distortion and total distortion + noise

Tables 16 and 17 show the arithmetic mean value (AM), the weighting mean value using all data (WM) and the weighting mean value using the largest consistent subset (WM – LCS) for measurements using a LS2P and a LS1P microphone respectively. The weighted means were calculated using the standard uncertainty as weighting factor and the largest consistent subset were calculated excluding the discrepant values, according to the procedure presented by Cox [6].

Table 16 – Mean values calculated for total harmonic distortion and total distortion + noise measurements using a LS2P microphone.

	Measurand [%]
THD (AM)	0.52
THD (WM)	0.28
THD (WM – LCS)	0.40[a]
TD + N (AM)	1.14
TD + N (WM)	1.12
TD + N (WM – LCS)	1.15[b]

Notes:

[a] LCS contains data reported by: CENAM, INMETRO, INTI, LACOMET and NIST.

[b] LCS contains data reported by: CENAM, INMETRO, LACOMET and NRC.

Table 17 – Mean values calculated for total harmonic distortion and total distortion + noise measurements using a LS1P microphone.

	Measurand [%]
THD (AM)	0.37
THD (WM)	0.38
THD (WM – LCS)	Not applicable[a]
TD + N (AM)	0.73
TD + N (WM)	0.76
TD + N (WM – LCS)	Not applicable[a]

Note:

[a] All data are consistent.

7.4 Measured total harmonic distortion, total distortion + noise and the calculated mean values

Figures 21 to 24 show the measured total harmonic distortion, total distortion + noise (with expanded uncertainties) as reported by the participants and the calculated mean values for measurements using a LS2P and a LS1P microphone.

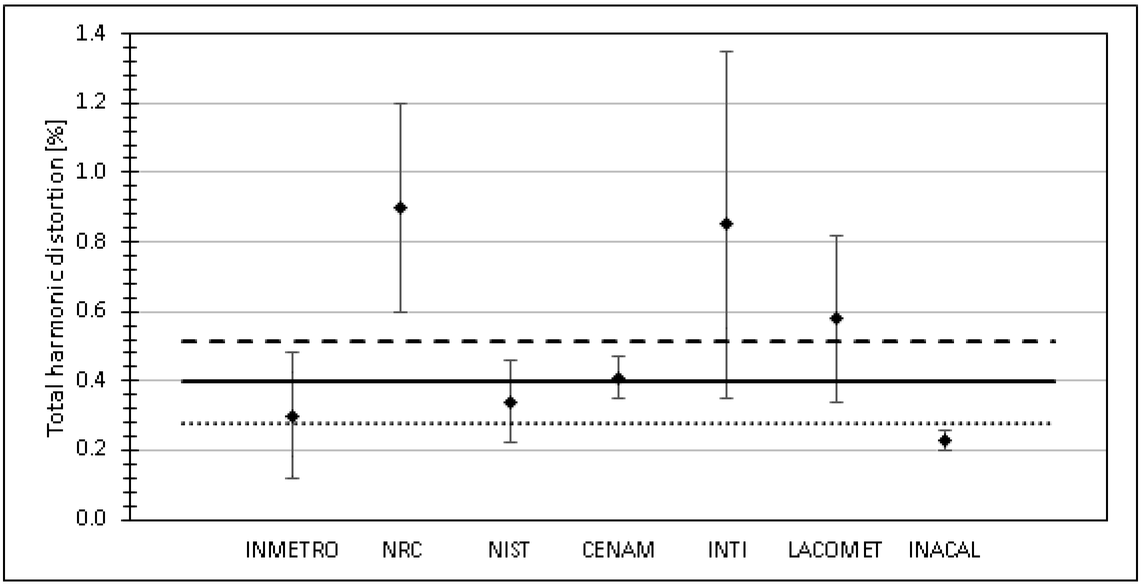


Figure 21 – Total harmonic distortion results reported by participants measured using a LS2P microphone. Solid line is the weighted mean value using the largest consistent subset (WM – LCS), dashed line is the arithmetic mean value (AM) and dotted line is the weighted mean value using all data (WM).

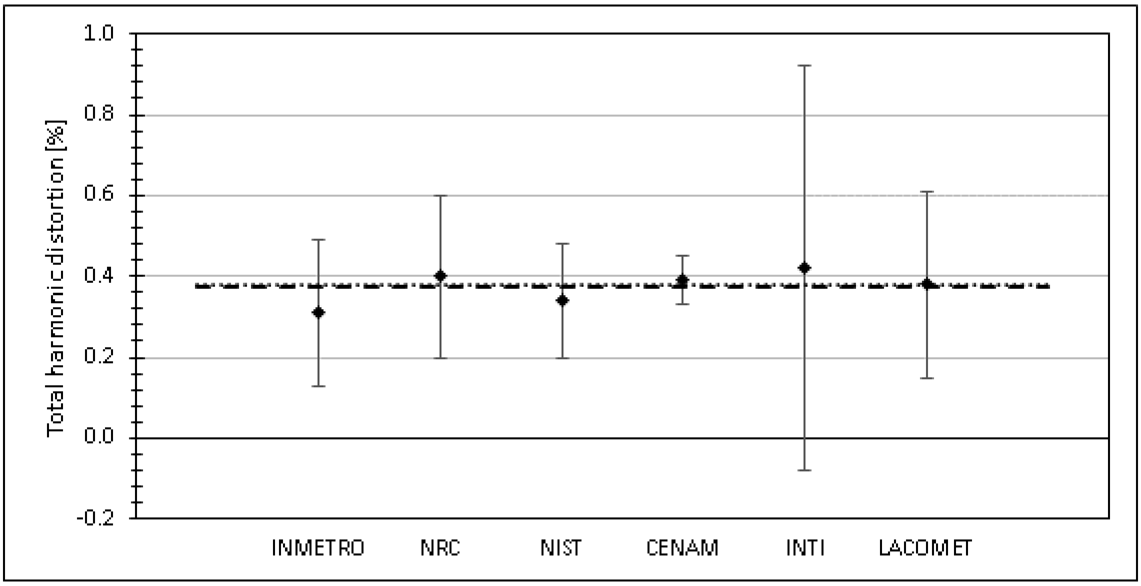


Figure 22 – Total harmonic distortion results reported by participants measured using a LS1P microphone. Dashed line is the arithmetic mean value (AM) and dotted line is the weighted mean value using all data (WM).

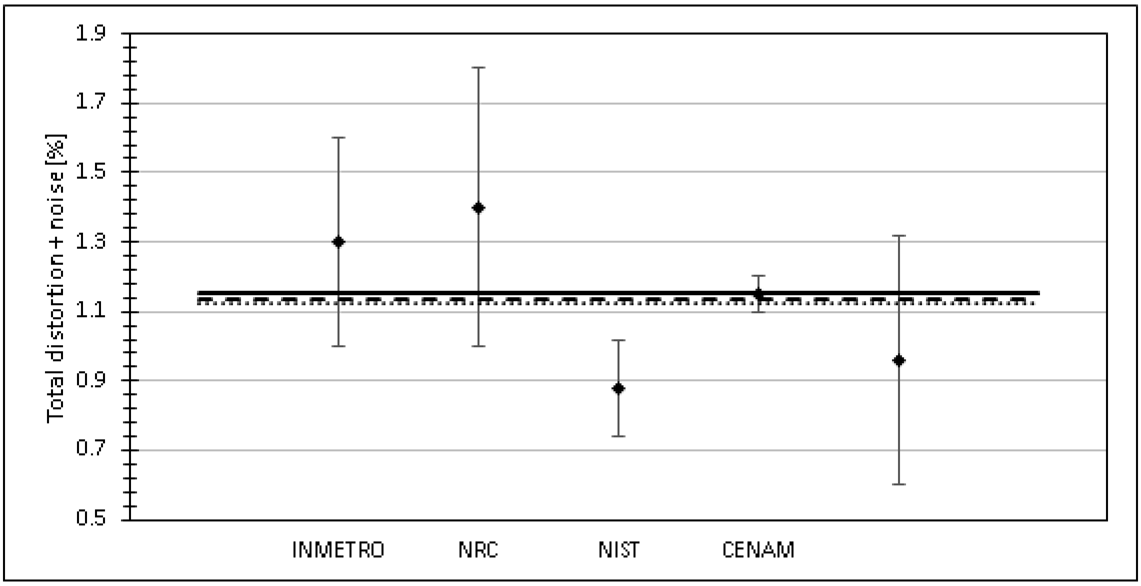


Figure 23 – Total distortion + noise results reported by participants measured using a LS2P microphone. Solid line is the weighted mean value using the largest consistent subset (WM – LCS), dashed line is the arithmetic mean value (AM) and dotted line is the weighted mean value using all data (WM).

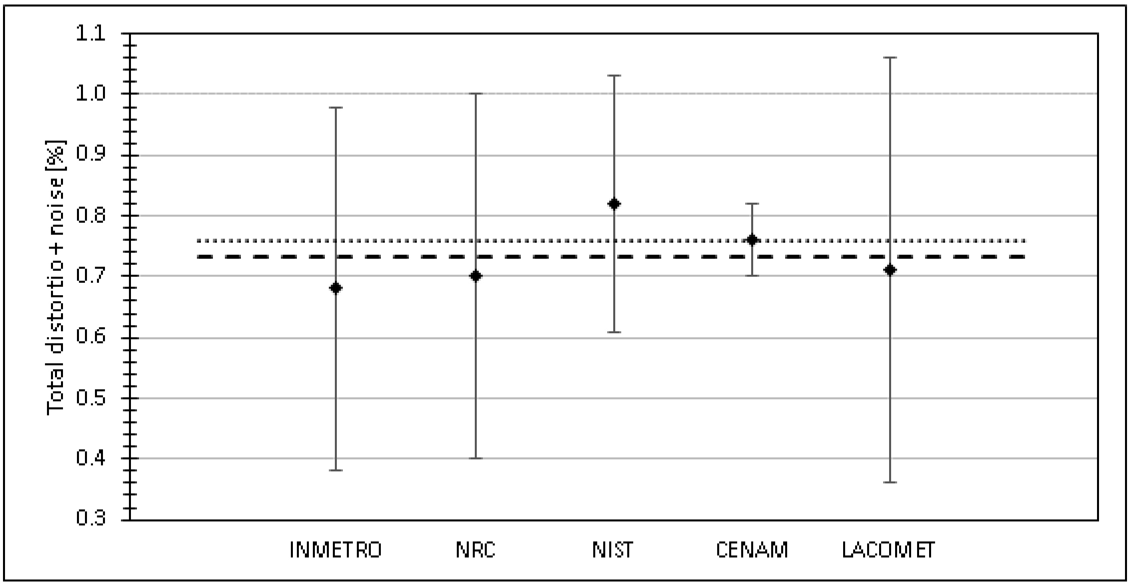


Figure 24 – Total distortion + noise results reported by participants measured using a LS1P microphone. Dashed line is the arithmetic mean value (AM) and dotted line is the weighted mean value using all data (WM).

8 COMMENTS

All participating NMIs presented consistent results for sound pressure level measurements and this comparison can be used to support their Calibration and Measurement Capabilities (CMCs). However, INACAL and LACOMET should expend efforts to improve their measurement uncertainties because the reported values exceed the maximum-permitted value stated in the international standard IEC 60942:2017. It should be observed that INACAL reported measurement results obtained by the sound calibrator comparison method and CENAM, by the “direct measurement” method.

In addition, all participating NMIs also presented consistent results for frequency measurements.

Concerning the total harmonic distortion and total distortion + noise measurements, supplementary comparison reference values were not determined. This was decided due to the notable variances observed in the check calibrations carried out by the pilot institute, with respect to its reported measurement uncertainty. Another reason was a large difference between the uncertainties of measurement reported by the participants for these results. The distortion (total harmonic distortion and total distortion + noise) results reported by participants are presented together with different calculated mean values (arithmetic mean value, weighted mean value using all data and weighted mean value using the largest consistent subset) in order to allow comparison between the results. It should be noted that measurement of total harmonic distortion is not required by IEC 60942:2017 and it was requested in this comparison only for the purpose of investigation.

Overall, the supplementary comparison SIM.AUV.A-S2 was considered successful and fit its purpose: it allowed us to compare the sound pressure level and frequency measurements and to note the dispersion on the distortion (total harmonic distortion and total distortion + noise) measurements and on their estimated uncertainties.

9 ACKNOWLEDGEMENTS

The pilot institute hereby acknowledges and appreciates the dedicated time and efforts in contributing to this comparison by all the participating NMIs.

10 REFERENCES

[1] BUREAU INTERNATIONAL DES POIDS ET MESURES. **Key and supplementary comparisons (Appendix B)**. Available in: <https://www.bipm.org/kcdb/comparison?id=1005>. Access in: October 23, 2019.

[2] BRÜEL & KJÆR SOUND & VIBRATION. **Products**. Available in: <https://www.bksv.com/en/products/transducers/acoustic/calibrators/4228>. Access in: October 23, 2019.

[3] INTERNATIONAL ELECTROTECHNICAL COMMISSION, **Electropedia: The World’s Online Electrotechnical Vocabulary, 551-20-13**. Available in: <http://www.electropedia.org>. Access in: April 08, 2020.

[4] INTERNATIONAL ELECTROTECHNICAL COMMISSION, **IEC 60942 Electroacoustics – Sound calibrators**, 4th ed. Geneva, 2017.

[5] COX, M. G., **The evaluation of key comparison data**, Metrologia, **39**, 589-595 (2002).

[6] COX, M. G., **The evaluation of key comparison data: determining the largest consistent subset**, Metrologia, **44**, 187-200 (2007).

[7] CIPM MRA-D-05, **Measurement comparisons in the CIPM MRA**, Version 1.6, 2014.

APPENDIX A – RESULTS SUBMITED BY INACAL

Table A.1 – First set of results submitted by INACAL measured using a LS2P microphone. Date of calibration: August 26th, 2019.

	Measured	**Expanded Uncertainty 95 %, *k* = 2**
SPL [dB (reference: 20 μPa)]	124.08	0.11
Frequency [Hz]	251.18	0.01
THD [%]	0.16	0.03

Table A.2 – Revised set of results submitted by INACAL measured using a LS2P microphone. Period of calibration: October 14th to 22nd, 2019.

	Measured	**Expanded Uncertainty 95 %, *k* = 2**
SPL [dB (reference: 20 μPa)]	123.95	0.12
Frequency [Hz]	251.17	0.01
THD [%]	0.23	0.03

APPENDIX B – REPORTED SPREADSHEET TEMPLATES

B.1 INMETRO

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the **one-inch to half-inch adaptor type DP 0776**, i.e. using a **half-inch reference measurement microphone**

National Metrology Institute	Inmetro

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
10 to12 of September 2018	23,0 to 23,8	101,586 to 101,858	49,5 to 53,4

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.951	0.07

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.17	0.1	0.304	0.18	1.299	0.30

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No, there are not.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
It was vertical with cavity up.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
The method used was the microphone method (insert voltage technique).

What was the reference measurement microphone's type used? Did you use a LS2P or another one?
It was used reference measurement microphones type LS2P.

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
0,08 dB
b) for the reference environmental conditions?
From 0,02 to 0,05 dB depending on the environmental conditions during the measurement.

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
The method used is the one that uses a FFT analyzer.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
No, I do not. Thanks.

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183

Results obtained using an **one-inch reference measurement microphone**

National Metrology Institute	Inmetro

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
10 to12 of September 2018	23,3 to 23,9	101,660 to 101,902	51,1 to 56,9

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.955	0.07

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.17	0.1	0.310	0.18	0.675	0.30

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No, there are not.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
It was vertical with cavity up.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
The method used was the microphone method (insert voltage technique).

What was the reference measurement microphone's type used? Did you use a LS1P or another one?
It was used reference measurement microphones type LS1P.

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
0,28 dB
b) for the reference environmental conditions?
From 0,03 to 0,05 dB depending on the environmental conditions during the measurement.

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
The method used is the one that uses a FFT analyzer.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
No, I do not. Thanks.

B.2 NRC

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the **one-inch to half-inch adaptor type DP 0776**, i.e. using a **half-inch reference measurement microphone**

National Metrology Institute	National Research Council of Canada

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
10/22/2018	23.32	100.660	22.69

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.971	0.07

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.17	0.2	0.87	0.3	1.40	0.4

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
The pistonphone was oriented vertically with the cavity up.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Microphone method (insert voltage technique).

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
LS2P (B&K Type 4180)

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
The load volume correction applied is -0.08 dB.
b) for the reference environmental conditions?
The correction for environmental conditions for the pistonphone is +0.054474 dB.

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
The distortion measurement instrument (Keithley 2015-P) performs a FFT on the signal and analyzes the levels of the harmonics present in the signal to calculate the chosen distortion quantities.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
None.

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183

Results obtained using an **one-inch reference measurement microphone**

National Metrology Institute	National Research Council of Canada

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
10/22/2018	23.22	100.689	29.75

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.983	0.08

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.17	0.2	0.40	0.2	0.73	0.3

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
The pistonphone was oriented vertically with the cavity up.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Microphone method (insert voltage technique).

What was the reference measurement microphone's type used? Did you use a LS1P or another one?
LS1P (B&K Type 4160)

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
The load volume correction used is -0.28 dB.
b) for the reference environmental conditions?
The correction for environmental conditions for the pistonphone is +0.052674 dB.

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
The distortion measurement instrument (Keithley 2015-P) performs a FFT on the signal and analyzes the levels of the harmonics present in the signal to calculate the chosen distortion quantities.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
None.

B.3 NIST

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the **one-inch to half-inch adaptor type DP 0776**, i.e. using a **half-inch reference measurement microphone**

National Metrology Institute	NIST (US)

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
11/8/2018	23.3	100.92	32

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.931	0.07 dB

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.171	0.12	0.337	0.12	0.875	0.14

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
Vertical with the cavity up, at the top of the pistonphone

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
The microphone method (insert voltage technique)

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
LS2aP

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
-0.080 dB
b) for the reference environmental conditions?
Total: 0.029 dB, Ambient Pressure: 0.035 dB, Relative Humidity: -0.006 dB

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
A rejection filter device

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
No

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183

Results obtained using an **one-inch reference measurement microphone**

National Metrology Institute	NIST (US)

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
11/7/2018	23.3	100.23	35

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.950	0.09 dB

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.172	0.12	0.342	0.14	0.818	0.21

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
Vertical with the cavity up, at the top of the pistonphone

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
The microphone method (insert voltage technique)

What was the reference measurement microphone's type used? Did you use a LS1P or another one?
LS1P

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
-0.280 dB
b) for the reference environmental conditions?
Total: 0.088 dB, Ambient Pressure: 0.094 dB, Relative Humidity: -0.006 dB

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
A rejection filter device

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
No

B.4 CENAM

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the **one-inch to half-inch adaptor type DP 0776**, i.e. using a **half-inch reference measurement microphone**

National Metrology Institute	CENAM

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
December 17,2018 to January 11,2019	23.2	101.31	53.6

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.904	0.08

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.172	0.01	0.412	0.06	1.147	0.05

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
Measurements are performed using an automated system which sequencially measures SPL, frequency and DT. Overall time to determine the three parameters is 90 seconds. Specified measurement period in Clauses A.5.5.1, A.5.7.1 and A.5.8.1 is shorter than the actual time used in measurements reported in here.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
The pistonphone was in vertical position with the cavity pointing upwards.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Direct measurement with 3 microphones LS2P.

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
Brüel & Kjær's LS2P, type 4180.

What was the value of the correction applied to the measured sound pressure level:							
a) for load volume corresponding to the used microphone?							
Serial Number	2208276	Load Volume Corr.	0.112404	dB			
Serial Number	1698197	Load Volume Corr.	0.112404	dB			
Serial Number	2208286	Load Volume Corr.	0.112404	dB			
b) for the reference environmental conditions?							
Mic. Serial Number		2208276					
Microphone Pressure Correction:			0.0005	dB			
Microphone Temperature + Humidity Correction:			-0.0004	dB			
Pistonphone Pressure Correction:			0.0009	dB			
Pistonphone Temperature + Humidity Correction Correction:			-0.0063	dB			
Mic. Serial Number		1698197					
Microphone Pressure Correction:			0.0011	dB			
Microphone Temperature + Humidity Correction:			-0.0005	dB			
Pistonphone Pressure Correction:			0.0020	dB			
Pistonphone Temperature + Humidity Correction Correction:			-0.0064	dB			
Mic. Serial Number		2208286					

(to be continue)

Microphone Pressure Correction:			0.0009	dB			
Microphone Temperature + Humidity Correction:			-0.0002	dB			
Pistonphone Pressure Correction:			0.0018	dB			
Pistonphone Temperature + Humidity Correction Correction:			-0.0060	dB			

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
Hewlett Packard Distortion Analyser, model 8903E.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183

Results obtained using an **one-inch reference measurement microphone**

National Metrology Institute	CENAM

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
2019-01-10	23.2	101.3	45.1

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.917	0.06

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.172	0.01	0.393	0.06	0.762	0.06

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
Measurements are performed using an automated system which sequencially measures SPL, frequency and DT. Overall time to determine the three parameters is 90 seconds. Specified measurement period in Clauses A.5.5.1, A.5.7.1 and A.5.8.1 is shorter than the actual time used in measurements reported in here.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
The pistonphone was in vertical position with the cavity pointing upwards.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Direct measurement with 3 microphones LS2P.

What was the reference measurement microphone's type used? Did you use a LS1P or another one?
Brüel & Kjær's LS2P, type 4160.

What was the value of the correction applied to the measured sound pressure level:								
a) for load volume corresponding to the used microphone?								
Serial Number	1734027	Load Volume Corr.	0.2978	dB				
Serial Number	1698020	Load Volume Corr.	0.2968	dB				
Serial Number	1734011	Load Volume Corr.	0.295	dB				
b) for the reference environmental conditions?								
Mic. Serial Number		1734027						
Microphone Pressure Correction:			0.0004	dB				
Microphone Temperature + Humidity Correction:			-0.0006	dB				
Pistonphone Pressure Correction:			0.0022	dB				
Pistonphone Temperature + Humidity Correction Correction:			-0.0050	dB				
Mic. Serial Number		1698020						
Microphone Pressure Correction:			0.0003	dB				
Microphone Temperature + Humidity Correction:			-0.0009	dB				
Pistonphone Pressure Correction:			0.0019	dB				
Pistonphone Temperature + Humidity Correction Correction:			-0.0049	dB				
Mic. Serial Number		1734011						

(to be continue)

Microphone Pressure Correction:			0.0003	dB			
Microphone Temperature + Humidity Correction:			0.0001	dB			
Pistonphone Pressure Correction:			0.0022	dB			
Pistonphone Temperature + Humidity Correction Correction:			-0.0058	dB			

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
Hewlett Packard Distortion Analyser, model 8903E.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?

B.5 INTI

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the **one-inch to half-inch adaptor type DP 0776**, i.e. using a **half-inch reference measurement microphone**

National Metrology Institute	INTI

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
01/03/19 to 21/03/19	20,1 to 24,9	100,2 to 102,1	44 to 64

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.970	0.08

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.17	0.1	0.850	0.50	NA	NA

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
Vertical position, cavity down.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Insert voltage technique method was used.

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
2 (two) type 4180 LS2P microphones.

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
+ 0,08
b) for the reference environmental conditions?
All ambient corrections are referred to normative reference conditions. As our laboratory couldn´t control the ambient barometric pressure, different individual corrections were applied on the complete calibration period. This corrections were made using pistonphone user´s manual, chapter 3, item 3.2.1 (eq. 3.3) for ambient barometric pressure. The humidity correction was -0,002 dB to all measuements. An amplificaction correction was already made to decrease microphone source/switch attenuation (Max. value 0,002 db).

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
NA

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
All the sound pressure level measurements were taken waiting between 20 to 25 seconds before the pistonphone was switched on.
The provided coupler PI 183 (B&K - DP 0776) was used.
PCA-124 SIM.AUV.A-S2 04/04/19

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183

Results obtained using an **one-inch reference measurement microphone**

National Metrology Institute	INTI

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
28/02/19 to 21/03/19	20,4 to 24,4	100,5 to 102,1	44 to 63

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.922	0.07

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.17	0.1	0.420	0.50	NA	NA

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
Vertical position, cavity down.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Insert voltage technique method was used.

What was the reference measurement microphone's type used? Did you use a LS1P or another one?
3 (three) type 4160 LS1P microphones were used.

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
+ 0,29 dB (this value was calculated with the measured real and equivalent microphones frontal volume, 250Hz).
b) for the reference environmental conditions?
All ambient corrections are referred to normative reference conditions. As our laboratory couldn´t control the ambient barometric pressure, different individual corrections were applied on the complete calibration period. This corrections were made using pistonphone user´s manual, chapter 3, item 3.2.1 (eq. 3.3) for ambient barometric pressure. The humidity correction was -0,002 dB to all measuements. An amplificaction correction was already made to decrease microphone source/switch attenuation (Max. value 0,002 db).

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
NA

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
All the sound pressure level measurements were taken waiting between 20 to 25 seconds before the pistonphone was switched on.
PCA-124 SIM.AUV.A-S2 04/04/19

B.6 LACOMET

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the **one-inch to half-inch adaptor type DP 0776**, i.e. using a **half-inch reference measurement microphone**

National Metrology Institute	LACOMET

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
April 8 to April 19, 2019	22.1	88.1	52

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.888	0.059

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.174	0.03	0.584	0.2	0.960	0.4

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No with respect to IEC 60942:2003

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
Was it vertical with the cavity up

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Insert voltage technique

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
LS2P Bruel & Kjaer 4180

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
Bruel & Kjaer 4180 = 0,08 dB
b) for the reference environmental conditions?
-1,212 dB

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
FFT analyzer (PC + software ARTA)

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
The toroid seal of the adapter from 1 " to 1/2" presented a noticeable wear, so I added a counterweight of 87,8 g to the set 1/2"microphone set
and its preamplifier to maintain verticality and equalize the weight of the set 1"microphone and its preamplifier.

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183

Results obtained using an **one-inch reference measurement microphone**

National Metrology Institute	LACOMET

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
April 8 to April 19, 2019	22.1	88.1	52

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.899	0.17

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.174	0.03	0.383	0.2	0.708	0.4

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
No with respect to IEC 60942:2003

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
Was it vertical with the cavity up

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
Insert voltage technique

What was the reference measurement microphone's type used? Did you use a LS1P or another one?
LS1P Bruel & Kjaer 4160

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
Bruel & Kjaer 4160 = 0,28 dB
b) for the reference environmental conditions?
-1,212 dB

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
FFT analyzer

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
The toroid seal of the adapter from 1 " to 1/2" presented a noticeable wear, so I added a counterweight of 87,8 g to the set 1/2"microphone set
and its preamplifier to maintain verticality and equalize the weight of the set 1"microphone and its preamplifier.

B.7 INACAL

Original results reported by INACAL.

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the one-inch to half-inch adaptor type DP 0776, i.e. using a half-inch reference measurement microphone

National Metrology Institute	INACAL

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
1 week	24,1	995,4	54,5

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
124,083	0,107

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251,176	0,005	0,161	0,030	-----	-----

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
The method of comparison was used.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
The instrument was oriented vertically with the cavity up.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
The comparison method was used by measuring the signal generated by the pistonphone and the signal generated by the function generator, in such a way to read the same values in the multimeter.

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
The microphone used was of type LS2P.

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
0,080 dB
b) for the reference environmental conditions?
-0,149 dB

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
Only measured THD, the method used was distortion factor meter.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?

The TDH+N test was not measured because the pattern was not calibrated for this function.

Revised results reported by INACAL.

Supplementary Comparison on Pistonphone Calibration SIM.AUV.A-S2

Artefact: Pistonphone manufactured by Brüel and Kjaer, type 4228, serial number 2836183, with its one-inch to half-inch adaptor type DP 0776

Results obtained with the one-inch to half-inch adaptor type DP 0776, i.e. using a half-inch reference measurement microphone

National Metrology Institute	INACAL

Period of the calibration	Air temperature (°C)	Static pressure (kPa)	Relative humidity (%)
1 week	23.1	995.5	63.5

Sound pressure level, dB re. 20 µPa (corrected for load volume corresponding to the microphone used and for the reference environmental conditions)	
Determined	Uncertainty (k = 2)
123.952	0.116

P.S.: The determined SPL should be reported with three decimals. The pilot laboratory will round it for two decimals.

Frequency, Hz		Total harmonic distortion, %		Total distortion + noise, % (measured over a bandwidth of 22.4 Hz to 22.4 kHz)	
Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)	Measured	Uncertainty (k = 2)
251.172	0.004	0.226	0.033	-----	-----

P.S.: The measured frequency, THD and TD+N should be reported with one decimal extra than their respective uncertainty. The pilot laboratory will round them for the same decimals number of the uncertainty.

Are there any deviations from IEC 60942:2017 (Periodic tests) in the technical procedure used?
The method of comparison was used.

What was the orientation of the pistonphone during the calibration? Was it horizontal? Was it vertical with the cavity up? Was it vertical with the cavity down?
The instrument was oriented vertically with the cavity up.

What was the method used to measure the generated sound pressure level? Did you use the microphone method (insert voltage technique) or another one?
The comparison method was used by measuring the signal generated by the pistonphone and the signal generated by the function generator,
in such a way to read the same values in the multimeter.

What was the reference measurement microphone's type use? Did you used a LS2P or another one?
The microphone used was of type LS2P.

What was the value of the correction applied to the measured sound pressure level:
a) for load volume corresponding to the used microphone?
-----(zero)
b) for the reference environmental conditions?
'-----(The 4228 pistophone is used as a pattern, so the correction errors are simplified by environmental conditions.)

What was the method used to measured the total distortion + noise? Did you use a rejection filter device (distortion factor meter) or a FFT analyzer?
Only measured THD, the method used was distortion factor meter.

Please, do not forget to submit your final uncertainty budget. The ISO document "Evaluation of measurement data - Guide to the expression of uncertainty measurement" shall be used as the reference document.

Do you have any additional information that you would like to share to the pilot laboratory?
The TDH+N test was not measured because the pattern was not calibrated for this function.

APPENDIX C – UNCERTAINTY BUDGETS

C.1 INMETRO

SPL - LS1P

Source of Uncertainty	Uncertainty contribuitions (dB) 250 Hz	*vi*
Calibration of microphone	0.0250	50
Drift of microphone	0.0065	50
Static pressure + Temp. - Mic&Pistonphone	0.0065	1000000
Polarisation voltage of the microphone	0.0050	1000000
Microphone volume	0.0115	1000000
Gain (insert voltage technique)	0.0050	1000000
Stability of the signal generator	0.0006	1000000
Digital multimeter HP3458A	0.0050	50
Rounding	0.0030	1000000
Repeatability	0.0115	2
Combined Uncertainty	0.0325	
veff	67	
Coverage factor, k	2.00	
Expanded Uncertainty	**0.065**	
Reported Expanded Uncertainty	**0.07**	

SPL - LS2P

Source of Uncertainty	Uncertainty contribuitions (dB) 250 Hz	*vi*
Calibration of microphone	0.0250	50
Drift of microphone	0.0181	50
Static pressure + Temp. - Mic&Pistonphone	0.0065	1000000
Polarisation voltage of the microphone	0.0050	1000000
Microphone volume	0.0115	1000000
Gain (insert voltage technique)	0.0050	1000000
Stability of the signal generator	0.0006	1000000
Digital multimeter HP3458A	0.0050	50
Rounding	0.0030	1000000
Repeatability	0.0058	2
Combined Uncertainty	0.0353	
veff	147	
Coverage factor, k	1.98	
Expanded Uncertainty	**0.070**	
Reported Expanded Uncertainty	**0.07**	

C.2 NRC

NRC uncertainty budget for Type 4228 sound calibrator with Type 4160 reference microphone

Component	Source	Estimated standard uncertainty	Sensitivity coefficient	Uncertainty contribution (dB)	Degrees of freedom
Measurements					
V_{ins}	Accuracy of insert voltage	0.001 dB	1	0.0010	6
$e(V_{ins})$	Error in indication	0.0017 dB	1	0.0017	6
ΔL_{V1}	Level difference	0.0173 dB	1	0.0173	185
ΔL_{rep}	Repeatability of SPL	0.02 dB	1	0.0200	50
ΔL_{res}	Resolution	0.0029 dB	1	0.0029	∞
T	Temperature	0.0289 °C	$-(\delta_T + K_T)$	0.0001	50
Ps	Barometric pressure	0.01 kPa	$-(\delta_{Ps} + 20 / (\ln(10).Ps))$	-0.0007	200
H	Relative humidity	3.82 %RH	$-K_H$	-0.0004	200
Sound calibrator					
K_T	Temperature coefficient	0.0003 dB/°C	$T - 23$	0.0006	50
ΔL_{Ps}	Effect of barometric pressure	negligible	1	negligible	200
K_H	Relative humidity coefficient	negligible	$H - 50$	negligible	50
ΔL_{vol}	Effect of load volume	0.0058 dB	1	0.0058	50
Reference microphone					
M_{ref}	Calibration of reference microphone	0.025 dB	1	0.0250	100
ΔM_{du}	Drift of reference microphone	0.0102 dB	1	0.0102	50
ΔM_{df}	Difference in frequency	negligible	1	negligible	50
δ_T	Temperature coefficient	0.0009 dB/°C	$T - 23$	0.0018	12
δ_{Ps}	Barometric pressure coefficient	0.0003 dB/kPa	$Ps - 101.325$	0.0009	12
ΔM_H	Effect of relative humidity	0.0007 dB	1	0.0007	12
ΔM_{pv}	Polarizing voltage	0.0015 dB	1	0.0015	50
Combined standard uncertainty				0.0385	280
Expanded uncertainty (k = 2)				**0.08**	

NRC uncertainty budget for Type 4228 sound calibrator with Type 4180 reference microphone

Component	Source	Estimated standard uncertainty	Sensitivity coefficient	Uncertainty contribution (dB)	Degrees of freedom
Measurements					
V_{ins}	Accuracy of insert voltage	0.001 dB	1	0.0010	6
$e(V_{ins})$	Error in indication	0.0017 dB	1	0.0017	6
ΔL_{V1}	Level difference	0.0173 dB	1	0.0173	185
ΔL_{rep}	Repeatability of SPL	0.02 dB	1	0.0200	50
ΔL_{res}	Resolution	0.0029 dB	1	0.0029	∞
T	Temperature	0.0289 °C	$-(\delta_T + K_T)$	0.0001	50
Ps	Barometric pressure	0.01 kPa	$-(\delta_{Ps} + 20 / (\ln(10).Ps))$	-0.0007	200
H	Relative humidity	3.82 %RH	$-K_H$	-0.0004	200
Sound calibrator					
K_T	Temperature coefficient	0.0003 dB/°C	T - 23	0.0006	50
ΔL_{Ps}	Effect of barometric pressure	negligible	1	negligible	200
K_H	Relative humidity coefficient	negligible	H - 50	negligible	50
ΔL_{vol}	Effect of load volume	0.0058 dB	1	0.0058	50
Reference microphone					
M_{ref}	Calibration of reference microphone	0.015 dB	1	0.0150	100
ΔM_{du}	Drift of reference microphone	0.0102 dB	1	0.0102	50
ΔM_{df}	Difference in frequency	negligible	1	negligible	50
δ_T	Temperature coefficient	0.0013 dB/°C	T - 23	0.0026	12
δ_{Ps}	Barometric pressure coefficient	0.0007 dB/kPa	Ps – 101.325	0.0021	12
ΔM_H	Effect of relative humidity	0.0023 dB	1	0.0023	12
ΔM_{pv}	Polarizing voltage	0.0015 dB	1	0.0015	50
Combined standard uncertainty				0.0331	269
Expanded uncertainty (k = 2)				**0.07**	

C.3 NIST

NIST Uncertainty Budget for Supplementary Comparison SIM.AUV.A-S2

Sound Pressure Level Output of Pistonphone with LS1P microphone

Source of Uncertainty	Type	Standard Uncertainty (%)
Microphone sensitivity as determined by comparison	B	0.38
Microphone sensitivity drift	A	0.16
Microphone sensitivity due to environmental effects	B	0.21
Microphone sensitivity change with frequency	B	0.01
Oscillator voltage measurement	B	0.07
Barometric pressure	B	0.07
Voltage ratio measurement	B	0.07
Polarizing voltage drift	B	0.07
Microphone volume departure from nominal LS1P acoustical load volume	B	0.06
Departure from nominal acoustical load volume due to assembly of microphone with pistonphone	B	0.07
Estimate of combined standard uncertainty (%)		0.49
Estimate of expanded (*k*=2) uncertainty (%)		0.98
Estimate of expanded (*k*=2) uncertainty (dB)		**0.09 dB**

NIST Uncertainty Budget for Supplementary Comparison SIM.AUV.A-S2

Sound Pressure Level Output of Pistonphone with LS2aP microphone

Source of Uncertainty	Type	Standard Uncertainty (%)
Microphone sensitivity as determined by reciprocity	B	0.21
Microphone sensitivity drift	A	0.16
Microphone sensitivity due to environmental effects	B	0.21
Microphone sensitivity change with frequency	B	0.01
Oscillator voltage measurement	B	0.07
Barometric pressure	B	0.07
Voltage ratio measurement	B	0.07
Polarizing voltage drift	B	0.07
Microphone volume departure from nominal LS2aP acoustical load volume	B	0.06
Departure from nominal acoustical load volume due to assembly of microphone with pistonphone and DP 0776 adapter	B	0.20
Estimate of combined standard uncertainty (%)		0.42
Estimate of expanded (k=2) uncertainty (%)		0.84
Estimate of expanded (k=2) uncertainty (dB)		**0.07 dB**

C.4 CENAM

Comparación regional en calibración de pistófonos. SIM.AUV.A-S2.
Presupuesto de incertidumbre para istófonos con micrófonos tipo LS1P.
Centro Nacional de Metrología. México.

Fuente de incertidumbre	Valor de la cantidad de entrada	Fuente de información	Incertidumbre original	Distribución	Incertidumbre estándar	Coeficiente de sensibilidad	Contribución [dB]	Grados de libertad
Presión acústica a condiciones de medición								
Tensión de salida del micrófono [mV]	1.4694	Análisis estadístico [V]	0.00003	A normal k = 1	0.06631	0.0059	1.53645E-07	6.48E+14
		Certificado de calibración [V]	0.0000086	B normal k = 2				
		Resolución del instrumento [V]	0.0000029	Rectangular k = 1				
Sensibilidad de la cadena de medición [mV/mV]	0.993888	Análisis estadístico [V/V]	0.000001	B normal k = 2	0.00050	-8.7393	1.88612E-05	100
Sensibilidad del micrófono a condiciones de referencia [dB re 1 V/Pa]	-26.84	Certificado de calibración [dB re 1 V/Pa]	0.0300	B normal k = 2	0.01500	-1.0000	0.000225	100
Presión estática [hPa]	1013.03	Análisis estadístico [hPa]	0.0230929	A normal k = 1	0.0384300	0.0017	4.1683E-09	14.17331275
		Certificado de calibración [hPa]	0.0105	B normal k = 2				
		Resolución del instrumento [hPa]	0.0289	Rectangular k = 1				
Factor de corrección por presión del micrófono [dB/hPa]	-0.00168	Certificado de calibración [dB/hPa]	0.00004	B normal k = 2	0.0000052	0.2225	1.09E-10	100
Temperatura [°C]	23.26	Análisis estadístico [°C]	0.0202	A normal k = 1	0.0874166	0.0025	4.77604E-08	96.4609123
		Certificado de calibración [°C]	0.0850	B normal k = 2				
		Resolución del instrumento [°C]	0.0029	Rectangular k = 1				
Factor de corrección por temperatura del micrófono [dB/°C]	-0.0025	Certificado de calibración [dB/°C]	0.0000	B normal k = 2	0.0000016	-0.2550	1.59E-12	60
Incertidumbre estándar combinada							0.015622639	116.8452416

(to be continued)

Fuente de incertidumbre	Valor de la cantidad de entrada	Fuente de información	Incertidumbre original	Distribución	Incertidumbre estándar	Coeficiente de sensibilidad	Contribución [dB]	Grados de libertad
Volumen del acoplamiento pistófono-micrófono								
Volumen efectivo del micrófono [cm^3]	0.668	Certificado de calibración [cm^3]	0.0084	B normal k = 2	0.0042	0.4555	3.73E-06	100
Volumen geométrico del pistófono [cm^3]	18.24	Certificado de calibración [cm^3]	0.32	B normal k = 2	0.16	0.0153	6.01E-06	100
Incertidumbre estándar combinada							0.003122275	169.2474008
Corrección por presión								
Presión estática [hPa]	1013.03	Análisis estadístico [hPa]	0.0231	A normal k = 1	0.0384	-0.0100	1.47686E-07	14.17331275
		Certificado de calibración [hPa]	0.0105	B normal k = 2				
		Resolución del instrumento [hPa]	0.0289	Rectangular k = 1				
Factor de corrección por presión del pistófono [dB/hPa]	0.01	Certificado de calibración [dB/hPa]	0.0001	B normal k = 2	0.0000	-2.0000	6.4E-09	100
Incertidumbre estándar combinada							0.000392538	14.20778856
Corrección por temperatura y humedad relativa								
Humedad relativa [%]	42.53	Análisis estadístico [%]	0.0606	A normal k = 1	0.8023	-0.0001	8.78044E-09	108.29
		Certificado de calibración [%]	0.3000	B normal k = 2				
		Resolución del instrumento [%]	0.0029	Rectangular k = 1				
Temperatura [°C]	23.26	Análisis estadístico [°C]	0.0202	A normal k = 1	0.0874	-0.0003	5.9502E-10	96.4609123
		Certificado de calibración [°C]	0.085	B normal k = 2				
		Resolución del instrumento [°C]	0.0029	Rectangular k = 1				
Incertidumbre estándar combinada							9.6827E-05	122.8309338
Nivel de presión acústica del pistófono								**123.92 dB**
Repetibilidad y reproducibilidad del NPA a condiciones de referencia								**0.0054**
Incertidumbre combinada del nivel de presión acústica a condiciones de referencia								**0.017**
Grados efectivos de libertad								**157.31**
t95.45%(neff)								**2.025**
Incertidumbre expandida del nivel de presión acústica a condiciones de referencia								**0.034**

Comparación regional en calibración de pistófonos. SIM.AUV.A-S2.
Presupuesto de incertidumbre para pistófonos con micrófonos tipo LS2P.
Centro Nacional de Metrología. México.

Fuente de incertidumbre	Valor de la cantidad de entrada	Fuente de información	Incertidumbre original	Distribución	Incertidumbre estándar	Coeficiente de sensibilidad	Contribución [dB]	Grados de libertad
Presión acústica a condiciones de medición								
Tensión de salida del micrófono [mV]	0.3625	Análisis estadístico [V]	0.00000	A normal k = 1	0.01453	0.0240	1.21205E-07	1.30E+16
		Certificado de calibración [V]	0.0000021	B normal k = 2				
		Resolución del instrumento [V]	0.0000029	Rectangular k = 1				
Sensibilidad de la cadena de medición [mV/mV]	0.983403	Análisis estadístico [V/V]	0.000001	B normal k = 2	0.00049	-8.8325	1.88612E-05	100
Sensibilidad del micrófono a condiciones de referencia [dB re 1 V/Pa]	-38.74	Certificado de calibración [dB re 1 V/Pa]	0.0500	B normal k = 2	0.02500	-1.0000	0.000625	100
Presión estática [hPa]	1013.16	Análisis estadístico [hPa]	0.0230929	A normal k = 1	0.0384300	0.0052	3.99344E-08	14.17331275
		Certificado de calibración [hPa]	0.0105	B normal k = 2				
		Resolución del instrumento [hPa]	0.0289	Rectangular k = 1				
Factor de corrección por presión del micrófono [dB/hPa]	-0.0052	Certificado de calibración [dB/hPa]	0.00004	B normal k = 2	0.0000052	0.0885	1.09E-10	100
Temperatura [°C]	23.21	Análisis estadístico [°C]	0.0202	A normal k = 1	0.0227303	0.0020	2.06667E-09	0.440956829
		Certificado de calibración [°C]	0.0850	B normal k = 2				
		Resolución del instrumento [°C]	0.0029	Rectangular k = 1				
Factor de corrección por temperatura del micrófono [dB/°C]	-0.002	Certificado de calibración [dB/°C]	0.0000	B normal k = 2	0.0000016	-0.2050	1.59E-12	60
Incertidumbre estándar combinada							0.025377638	106.0764926

(to be continued)

Fuente de incertidumbre	Valor de la cantidad de entrada	Fuente de información	Incertidumbre original	Distribución	Incertidumbre estándar	Coeficiente de sensibilidad	Contribución [dB]	Grados de libertad
Volumen del acoplamiento pistófono-micrófono								
Volumen efectivo del micrófono [cm^3]	0.0435	Certificado de calibración [cm^3]	0.0084	B normal k = 2	0.0042	0.4555	3.73E-06	100
Volumen geométrico del pistófono [cm^3]	15.4002	Certificado de calibración [cm^3]	0.32	B normal k = 2	0.16	0.0153	6.01E-06	100
Incertidumbre estándar combinada							0.003122275	118.928087
Corrección por presión								
Presión estática [hPa]	1013.16	Análisis estadístico [hPa]	0.0231	A normal k = 1	0.0384	-0.0100	1.47686E-07	14.17331275
		Certificado de calibración [hPa]	0.0105	B normal k = 2				
		Resolución del instrumento [hPa]	0.0289	Rectangular k = 1				
Factor de corrección por presión del pistófono [dB/hPa]	0.01	Certificado de calibración [dB/hPa]	0.0001	B normal k = 2	0.0000	-2.0000	6.4E-09	100
Incertidumbre estándar combinada							0.000392538	14.17876861
Corrección por temperatura y humedad relativa								
Humedad relativa [%]	54.07	Análisis estadístico [%]	0.0606	A normal k = 1	0.8023	-0.0001	8.73125E-09	108.29
		Certificado de calibración [%]	0.3000	B normal k = 2				
		Resolución del instrumento [%]	0.0029	Rectangular k = 1				
Temperatura [°C]	23.21	Análisis estadístico [°C]	0.0202	A normal k = 1	0.0227	-0.0004	6.46633E-11	0.440956829
		Certificado de calibración [°C]	0.085	B normal k = 2				
		Resolución del instrumento [°C]	0.0029	Rectangular k = 1				
Incertidumbre estándar combinada							9.37865E-05	108.4392867
Nivel de presión acústica del pistófono								123.93 dB
Repetibilidad y reproducibilidad del NPA a condiciones de referencia								0.0255
Incertidumbre combinada del nivel de presión acústica a condiciones de referencia								0.036
Grados efectivos de libertad								436.14
t95.45%(neff)								2.025
Incertidumbre expandida del nivel de presión acústica a condiciones de referencia								0.073

C.5 INTI

PLANILLA PARA EL CALCULO DE LA INCERTIDUMBRE DE CALIBRACION

Procedimiento: PEA08 LS1P	Calibración de pistonfón por técnica de tensión insertada (IEC60942/17)

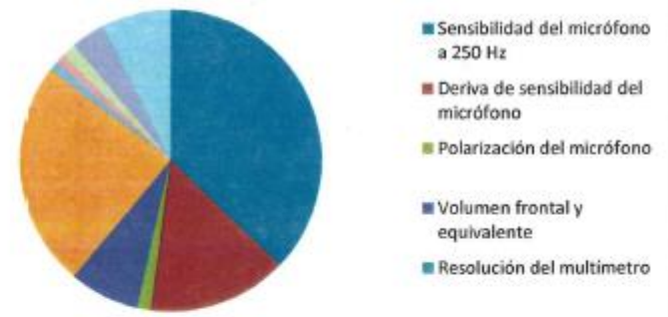
Fuente de incertidumbre	Símbolo	c_i (1)	Valor (±)	Distribución (2)	Factor	n_i (3)	u_i	u_i^2	W-S
Sensibilidad del micrófono a 250 Hz		1	0,050	N	2,0	10000	0,025	0,000625	3,90625E-11
Deriva de sensibilidad del micrófono		1	0,020	N	2,0	10000	0,010	0,0001	1E-12
Polarización del micrófono		1	0,002	R	1,7	10000	0,001	1,33333E-06	1,77778E-16
Volumen frontal y equivalente		1	0,010	R	1,7	10000	0,006	3,33333E-05	1,11111E-13
Resolución del multímetro		1	0,0001	R	1,7	10000	0,000	2,5148E-09	6,32421E-22
Exactitud del multimetro		1	0,033	R	1,7	10000	0,019	0,000352325	1,24133E-11
Presión atmosférica		1	0,001	N	2,0	10000	0,001	4,13493E-07	1,70976E-17
Temperatura ambiente		1	0,002	R	1,7	10000	0,001	0,00000075	5,625E-17
Factor de amplificacion		1	0,002	R	1,7	10000	0,001	1,33333E-06	1,77778E-16
Humedad relativa ambiente		1	0,005	R	1,7	10000	0,003	8,33333E-06	6,94444E-15
Error de redondeo		1	0,010	R	1,7	10000	0,006	3,33333E-05	1,11111E-13
Estimación de incertidumbre tipo B, k=1	u_c			N (1S)		25362	0,034		

Contribuciones Multimetro HP34401			
V (AC) 1 año	1,5	Vac	**20log**
Rango	10	0,00375	**0,0325**
Resolucion	0,00001	1,00001	**0,00009**

Fuentes de incertidumbres tipo A, dB re 20 mPa	
Incertidumbre tipo A, distribucion NORMAL (dB)	
Repetibilidad	0,011
Estimación de incertidumbre tipo A, k=1	0,011

Incertidumbre total, dB re 20 mPa			
Tipo A, N(95%)	k	2,0	0,022
Tipo B, N(95%)	k	2,0	0,067
Incertidumbre total, k=2			**0,070**

Incertidumbre final , dB re 20 mPa	**± 0,07**



2836183 - LS1P - PCA 124 - SIM AUV.A-S2

(1) Coeficientes de Sensibilidad
(2) N: normal; R:rectangular
(3) Grados de libertad

PLANILLA PARA EL CALCULO DE LA INCERTIDUMBRE DE CALIBRACION

Procedimiento: PEA08 LS2P	Calibración de pistonfón por técnica de tensión insertada (IEC60942/17)

Fuente de incertidumbre	Símbolo	c_i (1)	Valor (±)	Distribución (2)	Factor	n_i (3)	u_i
Sensibilidad del micrófono a 250 Hz		1	0,050	N	2,0	10000	0,025
Deriva de sensibilidad del micrófono		1	0,020	N	2,0	10000	0,010
Polarización del micrófono		1	0,002	R	1,7	10000	0,001
Volumen frontal y equivalente		1	0,010	R	1,7	10000	0,006
Resolución del multímetro		1	0,0001	R	1,7	10000	0,000
Exactitud del multímetro		1	0,033	R	1,7	10000	0,019
Presión atmosférica		1	0,001	N	2,0	10000	0,001
Temperatura ambiente		1	0,002	R	1,7	10000	0,001
Factor de amplificacion		1	0,002	R	1,7	10000	0,001
Humedad relativa ambiente		1	0,005	R	1,7	10000	0,003
Error de redondeo		1	0,010	R	1,7	10000	0,006
Estimación de incertidumbre tipo B, k=1	u_c			N (1s)		25362	0,034

u_i^2	W-S
0,000625	3,90625E-11
0,0001	1E-12
1,33333E-06	1,77778E-16
3,33333E-05	1,11111E-13
2,5148E-09	6,32421E-22
0,000352325	1,24133E-11
4,13493E-07	1,70976E-17
0,00000075	5,625E-17
1,33333E-06	1,77778E-16
8,33333E-06	6,94444E-15
3,33333E-05	1,11111E-13

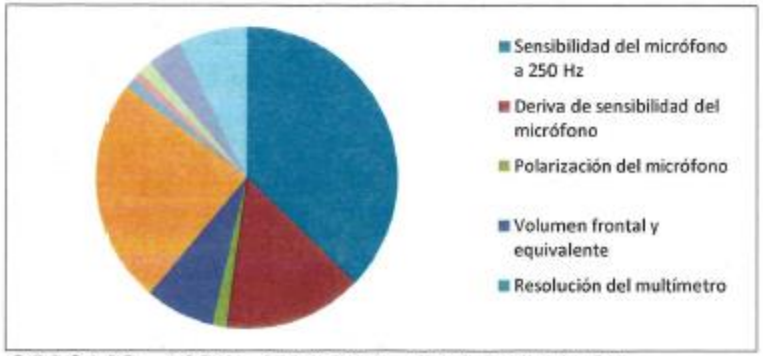
Contribuciones Multimetro HP34401

V (AC) 1 año	1,5	Vac	**20log**
Rango	10	0,00375	**0,0325**
Resolucion	0,00001	1,00001	**0,00009**

Fuentes de incertidumbres tipo A, dB re 20 mPa	
Incertidumbre tipo A, distribucion NORMAL (dB)	
Repetibilidad	0,024
Estimación de incertidumbre tipo A, k=1	0,024

Incertidumbre total, dB re 20 mPa				
	Tipo A, N(95%)	k	2,0	0,047
	Tipo B, N(95%)	k	2,0	0,067
Incertidumbre total, k=2				**0,082**

Incertidumbre final , dB re 20 mPa	**± 0,082**



2836183 - LS2P - PCA 124 - SIM AUV.A-S2

(1) Coeficientes de Sensibilidad
(2) N: normal; R:rectangular
(3) Grados de libertad

C.6 LACOMET

INCERTIDUMBRE CALIBRADOR 4160 LACOMET

Partiendo de (3b)

$$SPL_{cr} = SPL_{cm} - \Delta SPL_p - \Delta SPL_T - \Delta SPL_{hr} - \Delta SPL_V \quad (3b)$$

donde acorde al fabricante del equipo:

$$\Delta SPL_p = 20\ log_{10}(\frac{P_a}{1013\ hPa})$$

$$\Delta SPL_{hr} = \frac{1013\ hPa}{P_a}\ \Delta L + 0{,}0064$$

ΔL (dB) = -0,005 Esta corrección se obtiene de la Fig 3.4 del manual del equipo

$$\Delta SPL_V = -20\ log_{10}(\frac{V_{carga} + 18{,}4\ cm^3}{19{,}733\ cm^3})$$

NOTA: Para Mic B&K modelo 4180 = + 0,08 dB y para Mic B&K modelo 4160= + 0,28 dB

$$\Delta SPL_T = \delta T_c(T - T_{ref})$$

Tabla 4a. Incertidumbre de las magnitudes de entrada: condiciones ambientales y según manual Pistófono Tipo 4228

Magnitud X_i	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Distribución de probabilidad	Valor estimado x_i	Incertidumbre estándar $u(x_i)$
Presión	P_a	$u(P_a)$	Rectangular	88095	29
Humedad relativa	hr_a	$u(hr)$	Rectangular	52,32	1,62
Temperatura	T	u(T)	Rectangular	22,13	0,20
Corrección que se obtiene de la Fig 3.4 del manual	ΔL	u(ΔL)	Rectangular	-0,005	-0,0014

Tabla 4b. Contribuciones a la incertidumbre de las correcciones según manual Pistófono Tipo 4228

Magnitud X_i	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Distribución de probabilidad	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$ (dB)	Contribución a la incertidumbre $u_i(y)$ (%)
Corrección debida a la presión en el calibrador	ΔSPL_p	$u(\Delta SPL_p)$	Rectangular	$(20\ log_{10}(e)/P_a$	$(u(P_a)\ )(20\ log_{10}(e)/P_a$	**-1,2132**	**0,0029**			
Corrección debida a la temperatura en el calibrador	ΔSPL_T		Rectangular			**0,0004**	**0,0002**			
Coeficiente de temperatura calibrador	δT_c	$u(\delta T_c)$	Rectangular	$-(T - T_{ref})$	$-(T - T_{ref})\ u(\delta T)$	-0,0005	0,00014	0,868181818	0,00013	0,001
Temperatura	T	u(T)	Rectangular	$-\delta T_c$	$-\delta T_c\, u(T)$	22,1318	0,2040	-0,0005	-0,000102025	0,001
Corrección debida a la humedad relativa en el calibrador	ΔSPL_{hr}	$u(\Delta SPL_{hr}) = 101333\ u(\Delta L)/P_a$	Rectangular	$101333\ u(\Delta L)/P_a$	$101333\ u(\Delta L)\ /\ P_a$	**0,0007**	**0,0017**			

(to be continued)

$$SPL_{cr} = SPL_{cm} - \Delta SPL_p - \Delta SPL_T - \Delta SPL_{hr} - \Delta SPL_V \quad (3b)$$

$$dB = 20\ log_{10}\left(1+\frac{\%}{100}\right) \quad (1) \qquad \% = 100\left(10^{\frac{dB}{20}} - 1\right) \quad (2)$$

Tabla 4c. Contribuciones a la incertidumbre combinada del nivel de presión acústica en condiciones de referencia

Magnitud X_i	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Distribución de probabilidad	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$ (dB)	Contribución a la incertidumbre $u_i(y)$ (%)	% contribución a la incertidumbre
Nivel de presión en condiciones de medida	SPL_{cm}	$u(SPL_{cm})$	Normal	1	$u(SPL_{cm})$	122,9804	0,0339	1	0,03392	0,391	**28,5**
Corrección debida a la presión en el calibrador	ΔSPL_p	$u(\Delta SPL_p)$	Rectangular	-1	(-1) $u(\Delta SPL_p)$	-1,2132	0,0029	-1	-0,00286	0,033	**2,4**
Corrección debida a la temperatura en el calibrador	ΔSPL_T	$u(\Delta SPL_T)$	Rectangular	-1	(-1) $u(\Delta SPL_T)$	0,0004	0,0002	-1	-0,00016	0,002	**0,1**
Corrección debida a la humedad relativa del calibrador	ΔSPL_{hr}	$u(\Delta SPL_{hr})$	Rectangular	-1	(-1) $u(\Delta SPL_{hr})$	0,00065	0,0017	-1	-0,00166	0,019	**1,4**
Corrección debido al volumen de carga	ΔSPL_V	$u(\Delta SPL_V)$	Rectangular	-1	(-1) $u(\Delta SPL_V)$	0,280	0,081	-1	-0,08083	0,926	**67,5**
								u(dB) =	**0,0870**		**100,0**
								U(dB) =	**0,1739**		

INCERTIDUMBRE CALIBRADOR 4180 LACOMET

Partiendo de (3b)

$$SPL_{cr} = SPL_{cm} - \Delta SPL_p - \Delta SPL_T - \Delta SPL_{hr} - \Delta SPL_V \quad (3b)$$

donde acorde al fabricante del equipo:

$$\Delta SPL_p = 20\ log_{10}(\frac{P_a}{1013\ hPa})$$

$$\Delta SPL_{hr} = \frac{1013\ hPa}{P_a}\ \Delta L + 0{,}0064$$

ΔL (dB) = -0,005 Esta corrección se obtiene de la Fig 3.4 del manual del equipo

$$\Delta SPL_V = -20\ log_{10}(\frac{V_{carga} + 18{,}4\ cm^3}{19{,}733\ cm^3})$$

NOTA: Para Mic B&K modelo 4180 = + 0,08 dB y para Mic B&K modelo 4160= + 0,28 dB

$$\Delta SPL_T = \delta T_c(T - T_{ref})$$

Tabla 4a. Incertidumbre de las magnitudes de entrada: condiciones ambientales y según manual Pistófono Tipo 4228

Magnitud X_i	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Distribución de probabilidad	Valor estimado x_i	Incertidumbre estándar $u(x_i)$
Presión	P_a	$u(P_a)$	Rectangular	88095	29
Humedad relativa	hr_a	u(hr)	Rectangular	52,32	1,62
Temperatura	T	u(T)	Rectangular	22,13	0,20
Corrección que se obtiene de la Fig 3.4 del manual	ΔL	u(ΔL)	Rectangular	-0,005	-0,0014

Tabla 4b. Contribuciones a la incertidumbre de las correcciones según manual Pistófono Tipo 4228

Magnitud X_i	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Distribución de probabilidad	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$ (dB)	Contribución a la incertidumbre $u_i(y)$ (%)
Corrección debida a la presión en el calibrador	ΔSPL_p	$u(\Delta SPL_p)$	Rectangular	$(20\ log_{10}(e)/P_a$	$(u(P_a)\ )(20\ log_{10}(e)/P_a$	**-1,2132**	**0,0029**			
Corrección debida a la temperatura en el calibrador	ΔSPL_T		Rectangular			**0,0004**	**0,0002**			
Coeficiente de temperatura calibrador	δT_c	$u(\delta T_c)$	Rectangular	$-(T - T_{ref})$	$-(T - T_{ref})\ u(\delta T)$	-0,0005	0,00014	0,868181818	0,00013	0,001
Temperatura	T	u(T)	Rectangular	$-\delta T_c$	$-\delta T_c\, u(T)$	22,1318	0,2040	-0,0005	-0,000102025	0,001
Corrección debida a la humedad relativa en el calibrador	ΔSPL_{hr}	$u(\Delta SPL_{hr}) = 101333\ u(\Delta L)/P_a$	Rectangular	$101333\ u(\Delta L)/P_a$	$101333\ u(\Delta L)\ /\ P_a$	**0,0007**	**0,0017**			

(to be continued)

$$SPL_{cr} = SPL_{cm} - \Delta SPL_p - \Delta SPL_T - \Delta SPL_{hr} - \Delta SPL_V \quad (3b)$$

$$dB = 20\ log_{10}\left(1 + \frac{\%}{100}\right) \quad (1) \qquad \% = 100\left(10^{\frac{dB}{20}} - 1\right) \quad (2)$$

Tabla 4c. Contribuciones a la incertidumbre combinada del nivel de presión acústica en condiciones de referencia

Magnitud X_i	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Distribución de probabilidad	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$	Valor estimado x_i	Incertidumbre estándar $u(x_i)$	Coeficiente de sensibilidad c_i	Contribución a la incertidumbre $u_i(y)$ (dB)	Contribución a la incertidumbre $u_i(y)$ (%)	% contribución a la incertidumbre
Nivel de presión en condiciones de medida	SPL_{cm}	$u(SPL_{cm})$	Normal	1	$u(SPL_{cm})$	122,7640	0,0185	1	0,01849	0,213	**40,0**
Corrección debida a la presión en el calibrador	ΔSPL_p	$u(\Delta SPL_p)$	Rectangular	-1	(-1) $u(\Delta SPL_p)$	-1,2132	0,0029	-1	-0,00286	0,033	**6,2**
Corrección debida a la temperatura en el calibrador	ΔSPL_T	$u(\Delta SPL_T)$	Rectangular	-1	(-1) $u(\Delta SPL_T)$	0,0004	0,0002	-1	-0,00016	0,002	**0,3**
Corrección debida a la humedad relativa del calibrador	ΔSPL_{hr}	$u(\Delta SPL_{hr})$	Rectangular	-1	(-1) $u(\Delta SPL_{hr})$	0,00065	0,0017	-1	-0,00166	0,019	**3,6**
Corrección debido al volumen de carga	ΔSPL_V	$u(\Delta SPL_V)$	Rectangular	-1	(-1) $u(\Delta SPL_V)$	0,080	0,023	-1	-0,02309	0,266	**49,9**
								u(dB) =	**0,0297**		**100,0**
						-1,212		**U(dB) =**	**0,0594**		

C.7 INACAL

NPA nominal del calibrador:	124.0	dB	
Datos para el calculo de incertidumbre			
Pistofono			
Incertidumbre de calibracion	0.06	dB	Certificado trazabilidad del Cenam
Barometro			
Incertidumbre de calibracion	0.3	hPa	
Resolucion	0.1	hPa	
Estabilidad	0.5	hPa	
Factor de correcion			
Resolucion en tabla	0.1	dB	
Multimetro-pistofono			
Incertidumbre del certificado:	0.00010	V	
Resolucion al medir el pistofono:	0.00001	V	
Alcance al medir el pistofono:	10.00000	V	
Multimetro-calibrador			
Incertidumbre del certificado:	0.000028	V	
Resolucion al medir el calibrador:	0.000001	V	
Alcance al medir el calibrador:	1.000000	V	
Especificaciones del	0.0006		
multimetro al medir el pistofono:	0.0003		
Especificaciones del	0.0006		
Multimetro al medir el calibrador:	0.0003		
Microfono-Pistofono			
Incertidumbre del certificado:	0.05	dB	
Microfono-Calibrador			
Incertidumbre del certificado:	0.05	dB	
Amplificador-Pistofono			
Incertidumbre del certificado:	0.049	dB	
Amplificador-calibrador			
Incertidumbre del certificado:	0.049	dB	
Tabla del Calibrador			
Resolucion de la tabla:		dB	

(to be continued)

Desviacion estandar del pistofono (V)	Calibracion pistofono (dB)	Calibracion multimetro (V)	Resolucion mult-pisto (V)	Estabilidad multimetro (V)	Desviacion estandar del calibrador (V)	Calibracion multimetro (V)	Resolucion mult-pisto (V)	Estabilidad multimetro (V)	Certificado micro-pisto (dB)
0,00002	0,03	0,00005	0,0000029	0,0014	0,00003	0,00005	0,0000029	0,0005	0,025
Incertidumbre expandida en Porcentajes (%)									
0,00051	0,346	0,00117	0,000070	0,034	0,0021	0,0037	0,00022	0,042	0,288

(to be continued)

Certificado micro-pisto (dB)	Certificado ampli-pisto (dB)	Certificado ampli-cali (dB)	Desviacion Barometro (hpa)	Certificado Barometro (hPa)	Resolucion Barometro(hPa)	Estabilidad Barometro (hPa)	Factor correcion de tabla calibrador (dB)	Incertidumbre Combinada (%)	Incertidumbre Combinada (dB)
0,025	0,0245	0,0245	0,088	0,15	0,029	0,288675135	0,014		
0,288	0,282	0,282	0,009	0,015	0,003	0,029	0,166	1,381	0,12

APPENDIX D – LACOMET COMMENTS ON THE UNCERTAINTY REPORTED FOR SOUND PRESSURE LEVEL

The note "b", presented under Table 3, informs that "Despite of the uncertainty of measurement exceeding the maximum-permitted value (± 0.10 dB) stated in IEC 60942:2017 [4], the measurement result was considered for comparisons purposes."

During the process of reviewing the draft A report, LACOMET provided additional information about its uncertainty report for sound pressure level using a LS1P microphone. The following explanation was given by LACOMET:

"*…in the TECHNICAL PROTOCOL SIM.AUV.A-S2 it was established that:*

'Results shall be corrected for the load volume corresponding to the microphones used and for the reference environmental conditions specified in IEC 60942:2017 (air temperature: 23 °C*, static pressure: 101,325* kPa *and relative humidity: 50* % rh*) [2] using the information presented in the pistonphone user manual [4]. The user manual will be circulated with the artefact to avoid the use of a different source of data by the participants.'*

The corrections are given in table 3.1 of the user manual for the Bruel and Kjaer 4180 and 4160 microphones, but the manual does not give the uncertainty of such correction, so some criteria are required to estimate it, such as in the extreme case of, in the absence of information, using the same correction as uncertainty, a conservative criterion is to estimate the uncertainty from the correction treating it as a rectangular distribution (this was my case as you can confirm in the book of uncertainties sent , sheet '4. U cal cond. Reference, cell I32)', another option would be to use a fraction of the error to estimate uncertainty, but this criterion requires more information.

If equation (3.4) of the equipment manual is used, it is necessary to calculate the microphone front volume and the microphone equivalent volume, these data that are normally in the microphone calibration certificate or technical information of the manufacturer of this. In the case of the 1" microphone, it is possible since there is no adapter between the piston and the microphone, but in the case of the ½" microphone, the microphone front volume and the microphone equivalent volume is not enough since the middle is DP0776 adapter. In fact, the 'V_{load} actual effective load volume' of the Bruel & Kajer 4180 microphone with the DP0776 adapter has a value of 1.14 cm^3*, information that is not given in the microphone calibration certificate or in the pistonphone manual, is a little hidden but it is there in the Instruction Manual Bruel & Kjaer BE0168-13, page 7.*

The expanded uncertainty for the environmental reference conditions for the 1" microphone performing the calculations from equation (3.4) of the pistonphone user manual is 0.07 dB *and the uncertainty expanded and reported using the criterion of a rectangular distribution for the correction given in table 3.1 of the pistonphone user manual calibrator is 0.17* dB."